Leitz MPV-CD Critical Dimension Measurement System

Software Operation Manual

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SOFTWARE OPERATION MANUAL

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The MPV-CD is the critical dimension measuring system designed for precision, flexibility, and easy operation. It is the most powerful tool for measuring optical images available for routine manufacturing applications. It is controlled by a microcomputer so that the structures are measured automatically. The operator simply tells the MPV-CD which device to measure or chooses one of the standard ways of measuring. The computer has stored the necessary information about how to measure the image of this structure in the microscope. It calls this information out of the appropriate measurement data file and is ready for the operator to put the sample on the microscope.

The Leitz Autofocus will bring the sample to focus at the push of a button. There is no prefocus or waiting for the system to search for focus. It has been designed for ease of use - it's not even necessary to look in the microscope. Since the microscope has Autofocus, the system can be operated by looking at a television monitor. What is seen on the TV or looking through the microscope is the same. The sample has a thin bright line in the central part of the image. This line is a slit window, with a light shining through it so both the structure and the window aperture can be seen. Left and right arrows move the slit forward and reverse. It can rotate to scan from left to right, top to bottom, bottom to top, or anything in between. It can be lengthened to measure an irregular line or shortened to measure a curved structure such as a contact via. The slit or the stage is moved so that the slit is lined up parallel to the structure to be measured.

The MPV-CD measures the brightness of the sample through this slit window with a photometer. The photometer converts the light intensity to an electrical signal which the computer measures. A bright surface produces a high light level, and dark surface gives a low one. The MPV-CD will move this slit window across the structure and measures the sample as it moves. The result is a graph with the bright and dark lines of the sample plotted as high and low parts of the graphic profile. The computer will automatically measure the structure with the edge detection criteria chosen for this structure. The results will be displayed and can be printed out if desired.

The Autofocus is continuously and dynamically focusing so the operator can easily move to another part of the sample. The sample stays in focus as the stage is moved. This makes it easier to find the next structure and protects the sample from scratching. The Autofocus may be turned off if a low power objective is desired. When finished with this sample, the Defocus key will turn off the Autofocus and lowers the sample away from the objective. The stage lowers about a millimeter to allow the sample to easily be removed.

The basic concept of the MPV-CD is as follows:

A sample of the normal production device is measured in the Engineering Program. This program allows great flexibility in "teaching" the system how to measure that particular device. The essential parameters chosen for that measurement are stored in a measurement data file on the computer tape or floppy disc. Here the information is protected from power failure or other disaster. The operator may choose the measurement data file appropriate for any particular device. The operator does not make the decisions about thresholds, edges, speeds, and such. After placing the production device on the stage and aligning the slit to it, the structure is automatically measured.

Normal Start and Menu of Programs

The instrument must be completely set up and all cable connections correct. Insert the program cassette into the HP85 and switch the computer on. Once switched on, the computer automatically starts a test routine. This test checks if all the connections are complete and all components switched on (control unit, lamp power supply unit).

The LEITZ label is displayed while the program is loading. Various other messages are displayed during the loading and self-testing process. These displays contain important information for the service technician. The system's checking procedures take approximately one minute. Refer to the last part of this chapter for an explanation.

When loading and testing are complete, the Program Menu is displayed.

Important!

Every system has its own cassette, and it must be used with that system. It should remain in the computer during operation; all important data for the system are stored on this cassette. Exchanging the objectives without recalibrating or using the system cassette on another instrument can lead to major measurement inaccuracies.

PROGRAM MENU

This is the central menu allowing you to go to an from automatic operator measurement, to flexible engineering measurement, to adjustment of the microscope, to calibration for pitch or threshold. This menu also allows you to add or remove an objective from the system memory, duplicate data files to a backup tape, and change the Engineering Password.

Please type the number corresponding to the program you want. Some of the selections are protected by an Engineering Password.

Please Enter PROGRAM #

1. OPERATOR PROGRAM Keyboard

2. AUTOMATIC STAGE Measurement

3. ENGINEERING Measurement
(+Measurement File Creation)

4. STAGE PATTERN

5. CALIBRATION and ADJUSTMENT

6. Change Optics and Password

1. OPERATOR PROGRAM Keyboard is an automatic program for use after the system has been taught how to measure a structure, with input normally from the HP85 keyboard.

2. AUTOMATIC STAGE MEASUREMENT measures several dies on several wafers or masks or devices in a tray using the STAGE CONTROLLER and motorized stage.

3. ENGINEERING MEASUREMENT is the measurement program which teaches the system to measure a particular structure, and stores this procedure in a MEASUREMENT FILE to be used by the OPERATOR Programs and AUTOMATIC STAGE MEASUREMENT. Password

4. STAGE PATTERN teaches the motorized stage to move to a pattern of locations so that several structures on one wafer or mask or tray can be measured automatically. Password

5. CALIBRATION AND ADJUSTMENT

a. ADJUST tests ILLUMINATION and scans an empty field to test uniformity of illumination.

b. CALIBRATION calibrates for PITCH. This is the basis for correct measurement; each objective used for exact measurement must be calibrated. Password

c. THRESHOLD TEST measures a mask in transmitted light to calculate a suggested MEASUREMENT THRESHOLD. Password

6. CHANGE OPTICAL INFORMATION is a selection made when a different objective is to be used or positions exchanged on the revolving nosepiece of the vertical illuminator. In addition you may duplicate data files to another tape, and the password may be changed. Password

Selecting #7 will display the five objectives, with their nominal and calibrated magnifications.

```
OPTICAL PARAMETERS

1. . . .    Objective  16 X (  16.1 )
2. . . .    Objective  32 x (  25.1 )
3. . . .    Objective  80 X (  80.6 )
4. . . .    Objective 100 x ( 100.8 )
5. . . .    Objective 160 x ( 158   )
6.  Rev Factor . . . . 1 x
    Tube Factor  . . . 1.55 x
7.  Duplicating DATA files
8.  Change ENGINEERING PASSWORD
```

An objective is changed by pressing the position number, then Endline. A question is then asked to protect current calibration and insure that calibration will be done. Type the number of the objective, without "x".

Changing the revolver factor changes the magnification of all objectives and forces recalibration of all.

Duplicating data files is a step-by-step process with directions from the computer. It is, of course, most important that you do not confuse the tapes or copy over existing important files. If you wish to store several sets of data files on one tape, you must rename the previous files before choosing this menu option.

Changing the Engineering password requires that you know the present password. If this is lost, it can be recovered. Contact your Leitz Representative. You have three chances to answer with the password, then the system completely restarts itself.

```
OPTICAL PARAMETERS

1. . . . Objective  10 x (  10   )
2. . . . Objective  50 x (  49.8 )
3. . . . Objective  80 x (  79   )
4. . . . Objective 100 x ( 101.3 )
5. . . . Objective 160 x ( 158   )
6.  Rev Factor . . . . 1x
    Tube Factor  . . . 1.55 x
7.  Duplicating DATA files
8.  Change ENGINEERING Password

Type SELECTION NUMBER, then ENDLINE
8
Type ENGINEERING PASSWORD, then ENDLINE
 ?
CD
NEW PASSWORD may be any TWO characters,
except period or quotation mark
```

If problems are discovered, the following appears on the HP85 monitor:

Is the system on power and are all components connected together?
Check and start again

Please recheck all connections, switch off HP85 and switch it on again.

In addition to checking that the cables are connected and the components switched on, the system also tests the computer interface between the desk computer and the control unit. If the tape is correct for the electronic unit, the following appears on the monitor:

Eprom 301305.419004v1.1
Binary prgm. CD 2.4 DEC 08 84

If the program tape cassette is incorrect, the EPROM number and the code number of the binary program appear on the monitor:

Eprom # 301305.419004v1.1
NOT CORRECT CHECK SOFTWARE#

Check and start again

These print-outs contain important information for the service technician.

An additional check within this automatic test routine concerns the measuring-slit mechanism. The system moves the measuring slit from one end of the travel range to the other and back to the center. If the measuring slit can be exactly positioned, the following is displayed on the monitor:

Eprom# 301305.419004v1.1

Binary Prgm: CD 2 4 DEC 08 84

POS= 5000

and the system has concluded the automatic test.

If such is not the case, the actual measuring-slit position together with the comment "RESET" will be indicated and the automatic test routine repeated until the measuring slit has been satisfactorily positioned.

The Operator Programs are designed specifically for a production line. These programs use the measurement files created in the Engineering Program, so the operator is not required to make decisions about objectives, threshold, edges, etc. The operator simply chooses the measurement file appropriate to that device and level of production. Slit control, light control, and measurement start and printing are controlled from the keypad.

Selection of the Measurement File:

The Program starts with a menu display of all measurement files. Press "X" to return to the Program Menu.

Measurement Files:

A:IBMIBM	B:80X32%1-2
C:80X32%1-3	D:80X32%1-4
E:80X32%2-3	F:80X32%2-4
G:8032M1234	H:BiLayer23
I:RESIST-MET	J:80X20%M123
K:IBM8020E14	L:80X32%3-4
M:IBM5020E23	N:RSFLDec14
O:BL5032%E23	P:8032129
Q:BL50Cont	R:8032124
S:DECbostonl	T:POLYII OCP
U:IBMRES	V:POLYII OC

Press Key: A - V
or X=Exit

Press the letter of the alphabet for the file you want. The MPV-CD is automatically set to measure with the parameters from that file. The Measurement Menu is displayed:

Leitz MPV-CD Measurement System

Focus,Adjust Slit,Test Light,RUN
Keys:RUN,SPACEBAR,ARROWS

LOWER END Pos: 41.26 um

File:80X32%1-4 80 x Obj. #3
Leitz MPV-CD Measurement System

Focus ON/OFF=+ Defocus=-
Keys:RUN,GRAPH,COPY,PAPER,CLEAR

Name	Light	Reject	FILES/Exit
Dist	Stats	RotateL	RotateR

Notice that the autofocus message "LOWER END" tells you that the stage is down for loading with the autofocus off. Press the "+" key on the keyboard to bring the sample to focus.

```
Focus:Adjust Slit,Test Light, RUN
Keys:RUN,SPACE,BAR,ARROWS

IN FOCUS                    POS:  41.26 um

File:80X32%1-4              80 x Obj. #3
Leitz MPV-CD Measurement System

Focus ON/OFF=+              Defocus=-
Keys:RUN,GRAPH,COPY,PAPER,CLEAR
Name     Light.    Reject    FILES/Exit
Dist     Stats     RotateL   RotateR
```

The autofocus message is "IN FOCUS". The top line is a short sequence for measurement. The second line tells you which KEYS are active on the keyboard. The third line is the autofocus message and the POSITION of the measuring slit relative to the possible travel at this magnification. The name of the FILE you have chosen and which OBJECTIVE must be used is on the fourth line. The fifth line is a NAME line which you may change to your name, the sample number, date, process step, or whatever you want printed with the results. On the sixth line are keys important after a measurement.

The two lines on the bottom are the labels for the Special Function Keys, k1 to k8, located below the display. Use the SHIFT key while you press k5 to k8.

Press SPACEBAR to see what parameters will be used to measure and calculate the results.

```
Leitz MPV-CD Measurement System
PARAMETERS of file 80X32%1-4
Objective       :  80 x
Minimum Travel  :  12 um
Scan Time       :  2 sec
Threshold       :  32.0%
Smooth-Factor   :  4
100% Value      :  Max
Appr. CD Width  :  10.81 um
Add. Corr.      :  0 um
Mult. Corr.     :  1.000 *
Lower Limit     :  1 um
Upper Limit     :  70 um
Meas. Point 1   :  EDGE 1
Meas. Point 2   :  EDGE 4
TO PRINT PRESS COPY
```

Press SHIFT+COPY to print these on paper.
Press SPACEBAR again to return to the Measurement Menu.

Press SHIFT+k5 if you want to change the NAME MESSAGE. The following is displayed:

```
CURRENT NAME ID =
Leitz MPV-CD Measurement System
Type NAME ID in 32 characters,
then ENDLILNE
  ?
```

Type the message, then press ENDLINE.

```
CURRENT NAME ID =
Leitz MPV-CD Measurement System
Type NAME ID in 32 characters,
then ENDLINE
  ?
This Line=Operator/Wafer#/etc.
```

This name now appears on the Measurement Menu and will be printed each time you ask for a printout.

```
This Line=Operator/Wafer#/etc.

Focus,Adjust Slit,Test Light,RUN
Keys:RUN,SPACEBAR,ARROWS

IN FOCUS              Pos:  41.26 um

File:80X32%2-3         80 x Obj. # 3
This Line=Operator/Wafer#/etc.

Focus ON/OFF=+              Defocus=-
Keys:RUN,GRAPH,COPY,PAPER,CLEAR
Name     Light     Reject     FILES/Exit
Dist     Stats     RotateL    RotateR
```

Preparation for Measurement:

You should now adjust the slit so that it is appropriate for the structure you want to measure. The keypad and the HP 85 keyboard can be used to control the MPV-CD with the following functions:

Compact Keyboard Key	HP 85 Key	Function
↑	↑	Lengthening of measuring slit
↓	↓	Shortening of measuring slit
←	←	Measuring slit moves to left
→	→	Measuring slit moves to right
↖	INS/RPL	Measuring slit turns counter-clockwise
↗	-CHAR	Measuring slit turns clockwise

Before the first measuerment on a new sample, the light level should be checked. During a measurement scan, the relative light level should remain less than 1023. The target value for automatic adjustment is 800 on a scale of 0 to 1023.

To test this light level, move the slit to the brightest structure in the intended scan, and press k6 "LIGHT". The following display appears:

```
If ready press              END LINE
Auto-adjust press           SPACEBAR

808
##############################
```

The Photometer's light measurement is shown as a decimal value and as a line porportional to this value. If the MPV-CD is being used with an automatically adjustable lamp power supply, press the SPACEBAR and hold it down until the value reaches 800.

If the light level is over 1023, a warning beep sounds and the following suggestion is displayed:

```
If ready press              END LINE
Auto-adjust press           SPACEBAR
Adjust PMT or SLIT
1023
####################################
```

If the light level is too low, the following suggestion is displayed:

```
If ready press              END LINE
Auto-adjust press           SPACEBAR
INCREMENT GAIN
200
#########
```

The best light level can also be achieved by adjusting the high voltage to the Photometer.

Manual adjustment of the lamp power supply can also achieve proper light levels.

After the light level has been adjusted, press ENDLINE. Move the slit to the place for the start of the measurement. Start the measurement scan be pressing RUN.

To remind everyone to avoid causing vibrations,

DONT TOUCH THE MICROSCOPE
==========

A beep sounds after the measurement scan is complete. The results are displayed automatically:

```
Leitz MPV-CD Measurement System

Distance:                    6.31 um

IN FOCUS              Pos:   41.26 um
MEAN     = 6.308
Number   = 10
St.Dev   = .004
File:80X32%1-4          80 x Obj. #3
Leitz MPV-CD MEASUREMENT SYSTEM

Focus ON/OFF=+               Defocus=-
Keys:RUN,GRAPH,COPY,PAPER,CLEAR
Name     Light     Reject     FILES/Exit
Dist     Stats     RotateL    RotateR
```

The results are corrected by the factors entered in the Engineering Program. After the second measurement, the number of measurements, the statistical Mean, and the Standard Deviation are displayed also. Also shown is the objective, the threshold for detection, and the method of calculation of the structure dimension.

Important:

1. The results are rounded off to two digits after the decimal point.

2. The statistical values are calculated on the results before rounding.

3. The accuracy of the result is determined by the numerical resolution of the measurement distance. The following formula applies:

```
MEASUREMENT
  RESOLUTION = SCAN DISTANCE / 1000
```

with the distance of the measurement scan displayed when the GRAPH is drawn. This can be seen by pressing "GRAPH".

The results may be printed by pressing k1. The first measurement in a series will be labeled with the name message. Each measurement after this will be printed below this.

```
Measurement File:80X32%1-4
Leitz MPV-CD Measurement System

N:   1    Result:   6.30 um
N:   2    Result:   6.31 um
N:   3    Result:   6.31 um
N:   4    Result:   6.31 um
N:   5    Result:   6.30 um
N:   6    Result:   6.31 um
N:   7    Result:   6.31 um
N:   8    Result:   6.31 um
N:   9    Result:   6.31 um
N:  10    Result:   6.31 um
```

A measurements are taken in a series, the statistics are displayed:

```
Number    = 10
MEAN      = 6.308
St.Dev    = .004
80X32%1-4
Leitz MPV-CD Measurement System
```

The STATISTICS may be printed with k2.

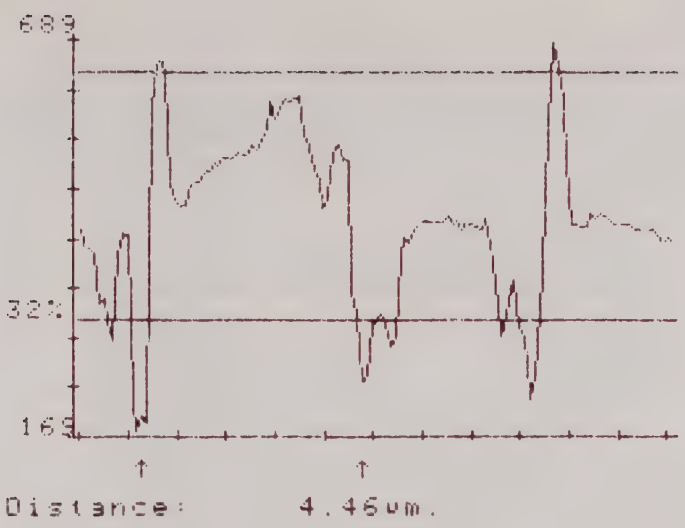
The current statistics may be cleared with the "CLEAR" key on the keyboard. Use this to start a new series on the next line or sample of the same type. Statistics are also cleared if you exit and choose the same file. If you exit "E", and decide you want to continue the statistical series, press "Z" on the keyboard at the File Menu.

The measurement result is accepted automatically if not rejected. This is one of the differences between Operator Program 1 and Program 2.

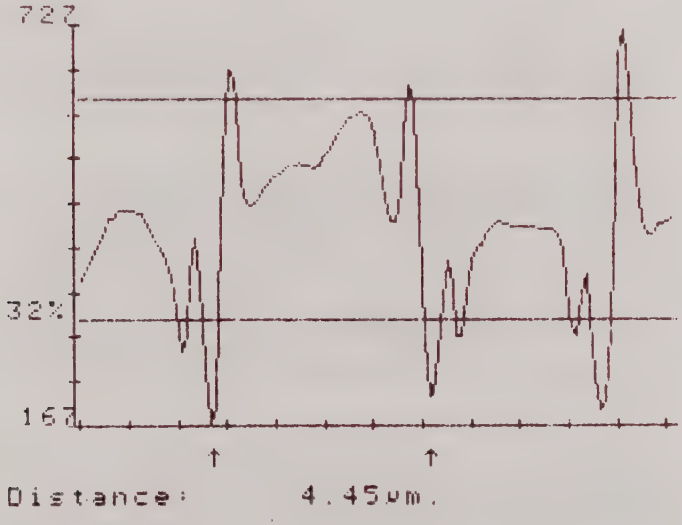
To reject this result, press k7 REJECT. This will cancel the current measurement. You may then make any adjustment necessary such as moving to the proper line.

Incorrect measurements may be caused by vibration, improper positioning of the slit, electronic noise if high levels of photometer gain and high voltage are used, or a measurement file which is not appropriate for the structure.

If a bad measurement occurs, drawing the GRAPH is the best way to see the source of the error. Press SHIFT+GRAPH.



The Graph of a measurement will be labeled with the measurement result. The graph may be printed out on paper by pressing COPY. Press SPACEBAR to return to the Menu.



After the measurement series is complete, press "-" on the keyboard to turn off the autofocus and lower the stage for sample change.

Then press k8 "FILES/Exit". This will take you back to the FILE MENU to choose another file for another type of sample or to exit to the Program Menu.

Sources for Error:

Since many measurement parameters were checked during the initial entry in the Engineering Program, the checks during the Operator Programs are limited to proper positioning of the slit in its range of travel, tests of structure width, and the type of structure.

If the slit runs to its limit of travel and triggers the endswitch, the computer beeps and displays:

ENDSWITCH REACHED ?

After repositioning the measuring slit, repeat the measurement.

If the measurement result is greater or less than the limits set for this file in the Engineering Program, the following message is displayed:

```
Leitz MPV-CD Measurement System

Distance:                    .04 um
Measurement OUT OF LIMITS

IN FOCUS                     Pos:  40.56 um

File:25%Mid1423              80 x Obj. # 3
Leitz MPV-CD Measurement System

Focus On/Off=+               Defocus=-
Keys:RUN,GRAPH,COPY,PAPER,CLEAR
Name     Light     Reject     FILES/Exit
Dist     Stats     RotateL    RotateR
```

Another test is for LIGHT LEVEL. If the light exceeds 1023 then the following is displayed. (Some structures may be measured properly this way: the message is for information.)

```
Distance:                    4.34 um
Light Level at Maximum!

IN FOCUS                     Pos:  40.81 um

File:80X32%2-3               80 x Obj. # 3
This Line=Operator/Wafer#/etc.

Focus ON/OFF=+               Defocus=-
Keys:RUN,GRAPH,COPY,PAPER,CLEAR
Name     Light     Reject     FILES/Exit
Dist     Stats     RotateL    RotateR
```

After the program is loaded and is running, the first display will be the Measurement Files Menu.

```
Measurement Files:
 A:  Default              B:  80x32%1-2
 C:  80X32%1-3            D:  80X32%1-4
 E:  80X32%2-3            F:  80X32%2-4
 G:  8032M1234            H:  BiLayer23
 I:  RESIST-MET           J:  80X20%M123
 K:  IBM8020E14           L:  80X32%3-4
 M:  IBM5020E23           N:  RSFLDecl4
 O:  BL5032%E23           P:  8032129
 Q:  BL50Cont             R:  8032124
 S:  Leitz                T:  POLYII DCP
 U:  IBMRES               V:  ContactVIA

 Choose Parameter File, Press A - V
 Space=Change Name   X=Exit,Menu
```

The operator makes a selection from this menu which corresponds to the sample to be measured. After this selection the program continues and prompts the operator to input a point filename.

```
Type name of stage file, ENDLINE
  (ENDLINE=                X=Exit)
  ?
```

This point file contains the information required to position the stage at the predetermined measurement points. If the operator chooses a stage file that does not exist the computer will inform the operator of the error and return to the Measurement Files Menu for reselection. Once a stage file has been selected the program then directs the stage through the Deskew process.

Deskew Process:

First the stage moves to the loading position and asks for the wafer to be placed on the stage and the STORE POSITION key be pressed once this is accomplished. The stage then moves to the first registration point. The operator is prompted to align the registration point with the crosshair reticle in the eyepiece using the stage direction keys or the trackball. The regisration points should be approached from the same direction each time alignment is done, this is to insure that the small amount of backlash in the screw mechanism is not a factor in the alignment. Once there is satisfactory alignment the operator presses the STORE POSITION key on the trackball panel. The stage then moves to the second registrationn point and the procedure is repeated. Upon pressing the STORE POSITION key the stage moves to the first measurement point, stops and shows the measurement menu:

Measurement Menu:

```
Measurement:  0um

IN FOCUS       Pos:  40.31um
Stage:X-022311   Y-4622   000
  Use Objective #3  80 X

Incremental Step Move (STEP&RUN)
LEITZ MEASURING STATION MPV-CD
Measurement File 05ADICD
Stage File STAGE3   Point 1
KEYS:k1--k8,ARROWS,SPACEBAR,RUN
Y,COPY,GRAPH,TEST,CONT,PLIST
NAME REMEASURE  UNLOAD   EXIT
Dist Light      RotateL RotateR
```

System Status:

At the top of the display is the value of the most recent measurement value, in this case since there has been no measurement taken, it is 0 microns. As in all of the CD programs the Autofocus status is displayed, as well as the position of the scanning slit in the field of view. Immediately below that is the current stage position in x and y. The three digits to the left of the stage coordinates show the state of keys on the trackball panel: STORE POSITION, STEP/SLEW and the unimplemented special function key. Additionally, the operator is prompted as to which objective to use for measurement, in this example it is objective number 3 on the nosepiece, 80x.

Program Status:

The first status line indicates the printer status. Normally the printer is on. To toggle the printer off, simply press the SHIFT key and the PLIST key, this will cause the "printer off" to be displayed and the printer will be disabled. Pressing the SHIFT and PLIST again will cause the line to display "printer on" and the printer will be reenabled.

The next status line indicates the mode in which the measurement is to proceed. The example shows that the program is in the incremental mode. In this mode the stage is directed to the next measurement point with the STEP key or the # key on the keypad.A measurement is taken with the RUN key or the 'M' key on the keypad. To move the program into the continuous mode, the operator has to press the CONT key and the display will read "mode: continuous meas." showing it is in the continuous mode. To trigger automatic measurement and movement press the RUN or the M key on the keypad, the MPV-CD then measures, displays the measurement results and automatically moves to the next point and repeats the cycle. If there is a circumstance where the measurement is out of limits or the light is wrong or there are not enough edges to calculate the linewidth, the sequence will halt and the menu will be displayed. While in the continuous mode, there is a feature which enables the operator to pause or

halt the sequence while any key is pressed. If in the case of a misaligned wafer the stage doesn't position correctly to the measurement structure, any key pressed and held (either on the HP-85 or the keypad) during the pause after the stage is positioned will cause the system to pause until proper alignment can be made with the 517 trackball. Any key held down after the measurement is taken will cause the measure-move sequence to be halted and the program returns to the menu.

The next line indicates the type of stage pattern, either Normal operation or Box operation. A display of 'Normal Stage Operation' indicates that the pointfile contains discrete points for the stage to move to consecutively. A Box pattern pointfile contains data that enables the program to calculate and move to points in a raster scan fashion.

General Information:

Other lines displayed in the menu are for informational purposes. The line that is shown as; "LEITZ MEASURING STATION MPV-CD" is an identification name which can easily be changed by pressing the SHIFT and k5 key (labelled as 'Name' in the menu). This line can be any alpha numeric input up to 32 characters in length, it is also displayed on the printer at the end of the measurement cycle. The next line of the menu shows what the name of the measurement file is in this example it is 'Ø5CADICD'. Below that in the display the stage file name is shown as well as the point in that file where the stage is currently positioned. The next two lines merely show the operator which keys are active in this program. ARROWS indicate that the cursor keys which the operator uses to maneuver the slit are active (on the keypad as well as the HP-85 keyboard). The 'Y' key (again on the keypad as well as the HP-85) is pressed to accept the measurement value. This is done automatically in the continuous mode. The GRAPH key on the HP-85 will draw a graph of the intensity profile and the edges used in the calculation of the line width. The other keys have been explained previously.

Key Labels:

At the bottom of the screen the labels for the special function keys are shown.

Dist (k1) prints the measurement value on the printer.

Light (k2) enters the lamp intensity setting routine. The key is equivalent to the 'P' key on the keypad.

RotateL (k3) and RotateR (k4) allow rotation of the measuring slit, these keys are equivalent to the rotate arrows on the keypad.

Name (k5) prompts the operator to enter a new measurement identification.

Remeasure (k6) enters a routine where the operator can reenter the measurement sequence at any point in the file.

Unload (k7) ends the measurement cycle and returns the stage to the load position.

Exit (k8) gives the operator the choice of exiting the program and returning to the main program menu, continuing measurement, entering a new measurement file, or directing the stage to the loading position.

PLIST toggles the printer on and off, its status is displayed on the HP-85.

CONT toggles the system between 'STEP and RUN' or 'Continuous Meas.'

SPACEBAR displays the current measurement parameters. Pressing SPACEBAR again will return to the measurement menu.

Once a measurement cycle is complete the program returns to the measurement files menu. If the next cycle is going to use the same measurement file, then merely press ENDLINE to proceed, the previous measurement file is the default. The same is true with the stage file selection, press ENDLINE to keep the previous stage file.

ENGINEERING MEASUREMENT PROGRAM

The Engineering Program allows the full flexibility of the system to be used to measure a structure. This sample structure is measured to teach the system how to measure it (learn mode). The way you choose to measure is stored in the computer so that similar structures can be measured automatically.

There are four menus in this program. Pressing KEYLABEL rotates these in order. Pressing RUN at any time starts a measurement scan with the current parameters. The system is operated primarily through the eight SPECIAL FUNCTION KEYS below CRT. The bottom row on the CRT are four labels for keys k1 to k4. The second row on the CRT labels keys k5 to k8. Press the shift key, then the function key needed.

Leitz MPV-CD Program Loading

PRE-RUN MENU

Current system values are displayed. Change any value by pressing the appropriate function key.

```
PreRUN Menu:KEYLABEL = Next Menu
Push RUN to Start MEASUREMENT
Push DISPLAY Keys to alter Value
Push COPY to Print Display
Objective          :  80 x
Travel             :  12 um
Smooth             :  4
Speed              :  2 secs
Threshold          :  32%
100% Thres.        :  Maximum
Sample Name:
.....................................
Measurement File: Default
Meter/in  Name   Objective  Exit
Threshold Travel Smooth     Speed
```

k1. The MEASUREMENT THRESHOLD is displayed as default value for an endline question. Limits are 1 to 99. The setting of the 100% threshold has two alternatives. MAXIMUM averages around the brightest part of the scan is a universal setting, and must be used for bright lines. BACKGROUND averages the first part of the scan to set the 100% level; this can be used for dark lines or lines of low contrast.

k2. The approximate dimension of the structures to be scanned is needed. This TRAVEL WIDTH is multiplied by 1.2 and rounded up to a unit of distance.

k3. Type a value of SMOOTHING. This is a moving average of the 1000 data points and helps to eliminate electronic noise and vibration. The value is the number of repetitions

k4. Type duration of the scan in seconds. Limits are 1 and 20. The speed and travel are evaluated by the computer and, if not correct, the question is asked again.

k5. This determines the unit of measure, metric or inch.

k6. Sample name allows the entry of a line of 32 characters which will be displayed and printed on result printouts.

k7. This tells the system it is measuring with a specific objective.

k8. This is a general exit from the measurement process and can branch back to continue measuremt, go back to the learn mode, or go to the program menu.

This menu allows adjustment and alignment of the measuring slit to the structure. The four cursor control keys are now active for this step. Up-arrow lengthens the slit; Down-arrow shortens the it. Right-arrow moves the slit in the direction of the scan and Left-arrow moves it backward. (These can be used when the slit is horizontal to test the direction of the scan.) Use k3 and k4 to Rotate slit (over 200 degrees). Note you can measure from left-to-right, top-to-bottom, bottom-to-top, or any orientation in between.

```
IN FOCUS                Pos:34.5um
Run Menu:Push RUN or KEYLABEL
LEFT, RIGHT ARROWS to move slit
UP,DOWN ARROWS to change Length
FOCUS keys ON/OFF=change lenses
Learn Mode
Lower Limit: .1um
Upper Limit: 70um



------------------------------
Defocus CalFact Limits   Exit
Focus   Light  RotateL RotateR
```

1. Use these controls to align slit to the structure edge. Lengthen it to maximum. Move it to the edge (on a dark line next to a bright edge is easiest). Rotate until the two are parallel. Shtorten slit to a lenght suitable to the structure. A suggested slit length is one in the middle of possible lengths, step 4 or step 5. A longer slit aperature can be used on granular surfaces to ignore the effects of particle boundaries, or on jagged edges to average out this effect. A short slit, down to a square, can be used to measure the diameter of a curved structure such as a contact hole.

2. Before a measuement is can be started the photometer's signal should be checked. During a measurement this signal should remain within a range of values of 200 to 1023. The target value of 800 should be used if possible.

To check the photometer's signal, move the measuring slit to the brightest spot of the structure to be investigated. Press k2 (Light). The following print-out appears on the screen:

```
If ready press          ENDLINE
Auto-adjust press         SPACEBAR

  804
################################
```

In the line above the bar (to the left) is the photometer's measured value. The lenght of the bar is proportional to this value.

If in the measuring system is equipped with an adjustable stabilized power unit, an automatic adjustment of the illumination level is possible.

After pressing the SPACEBAR the level of the illumination is changed until a photometer signal value of approximately 800 results. Should the illumination level exceed 1000 or fall below 400 a warning is displayed in the monitor:

If ready press ENDLINE
Auto-adjust press SPACEBAR
INCREMENT GAIN
######

The desired photometer signal value is also obtained by setting the high voltage and/or the photometer gain.

If an automatic adjustment of the illumination level is not available, the manual adjustment of the high voltage and of the photomter gain will achieve the desired photometer signal value.

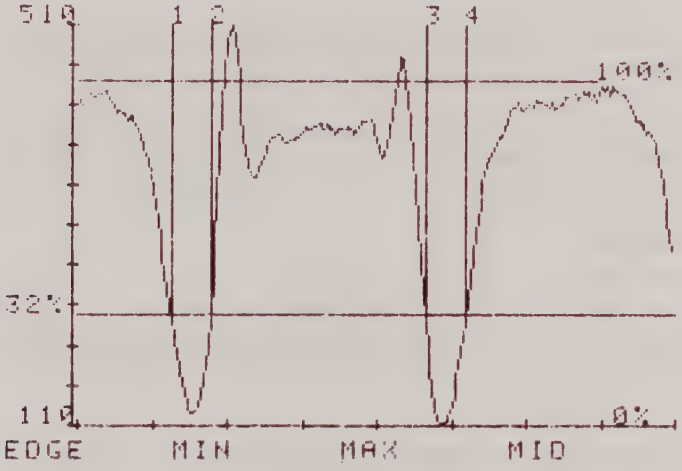
A warning signal sounds when the photometer signal exceeds a value of 1000.

Adjustment of the photometer's signal is completed with ENDLINE.

Move back to the starting position of the measuremnt scan and press RUN.

GRAPHICS PROFILE

The image is scanned, and a graphic display of the intensity profile is drawn. Note the scan travel distance is temporarily displayed. The scan can be reRUN immediately if something is incorrect; press KEYLABEL at this time branches to the RUN menu for adjustment. If at any time you want to START from the beginning, or return to the PRE-RUN MENU, or return to the PROGRAM MENU, press k8 and you will be asked where you want to go.



1. The DETECTION THRESHOLD is drawn across the intensity profile. The MEASURING POINTS are labeled at the intersections of the threshold and the profile. Edges very close together may be detected but the labels suppressed if they would be typed on top of each other. Additionally, edges at the extreme start of the scan are ignored.

Press k1 to k4 to choose the mode of measurement for one end of the measurement. Press the number of the EDGE points or the numbers if two points are required. Then press ENDLINE to tell the computer you have made your choices.

Press k1 to k4 again to choose the mode of measurement for the other end of the measured distance, then press ENDLINE to tell the computer you have made your other choice.

For example, press k1 EDGE. Press the number of the edge desired. Then press ENDLINE again to tell the system you have made your choice.

Choice of MINIMUMS, MAXIMUMS or MIDPOINTS require entry oftwo points. The measurement will be displayed under the graph. You have the option of printing the graph by pressing SHIFT and COPY.

Press KEYLABEL or SPACEBAR to proceed to the ANALYSIS menu.

Important:

1. The displayed measured and possible corrected value is rounded off to 2 digits after the decimal point.

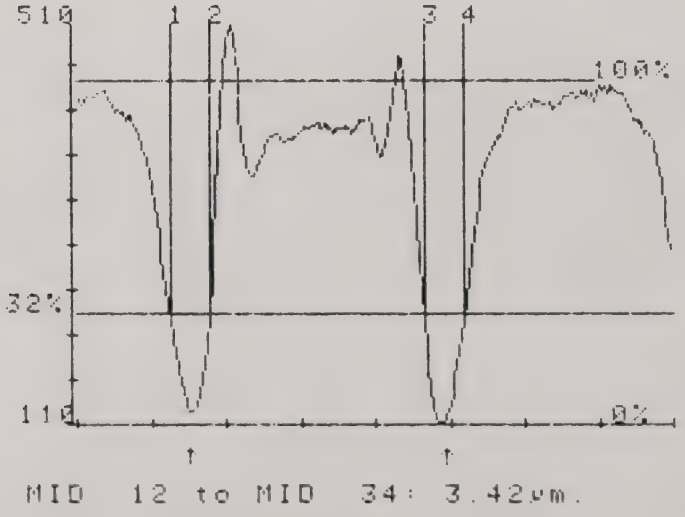
2. The accuracy of the measurement is determined by the numerical resolution of the measurement distance. The formula below applies:

   MEASUREMENT
   RESOLUTION = SCAN DISTANCE / 1000

   with scan distance of the measuring slit (in reference to the object) during the measurement process as displayed when the GRAPH is drawn.

A more detailed explanation follows:

The measurement positions can be either the intersection points of the intensity profile with the threshold, the midpoints of these intersection points or also the minimums or maximums between these intersection points (see also graph below).



An explanation of the individual keys follows:

k1: Type of measurement chosen is with an intersection point (EDGE). After selection of this kind of measurement, the number of the chosen intersection point must be entered.

k2. Type of measurement chosen is with a minimum (MIN). The minimum is between two intersection points that are to be entered.

k3. Type of measurement chosen is with a maximum (MAX). The maximum is between two intersection points that are to be entered.

k4: Type of measurement chosen is calculated as the midpoint between the two selected points. This can be used for a midpoints pitch of two lines, a linewidth based on the midpoints of the defraction lines, or an overlay calculation when the midpoint of an outside structure is measured to the midpoint of an inner structure.

Structure width is determined in the following manner:

1. Selection of the type of measurement to be used for the first measurement position by depression of key k1-k4.

2. Input of the desired intersection point (1-9) or of the desired intersection-point combination (1-9) and completion of entry for this measurement position with ENDLINE. A correction of the intersection-point choice is possible before completion of the entry via BACK SPACE key.

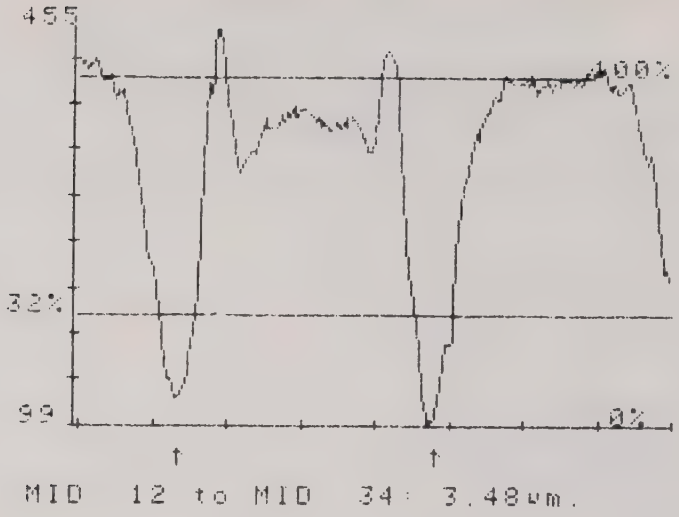
3. Selection of the type of measurement to be used for the second measurement position by pressing of k1-k4.

4. Input of the desired intersection point or intersection-point combination corresponding to point 2. The structure-width value appears in um in the last line on the monitor. Furthermore, two arrows marking the measurement positions are displayed in the lower part of the graph.

5. Completion of structure width calculation by pressing ENDLINE.

In the following example the center-to-center distance of two Cr lines on a mask was determined according to the above procedure.

For the first measurement position "MID", "1", "2" and END LINE are entered in the order given, for the second position "MID", "3", "4" and ENDLINE, the following printout appears on the monitor:



When ENDLINE is pressed again, the graph is displayed with the measurement result.

Possibilities of Error:

Before starting the measurement the program checks the entered measurement parameters, such as objective magnification, measurement time and measurement distance.

If the objective chosen is not calibrated, the message below appears on the monitor:

OBJECTIVE not Used,Calibrated
Enter Nominal Magnification,
Then ENDLINE
?

If no objective magnification was assigned to the code number entered, the following is displayed on the monitor:

OBJECTIVE not Used,Calibrated
Enter Nominal Magnification,
Then ENDLINE
?

When the combination of parameters entered is incorrect, the following comment, accompanied by a beep, is displayed on the monitor:

LINEWIDTH GREATER THAN FIELD

or

SPEED ERROR

and the program returns to start for re-input of the measurement parameters.

Another error can occur when measuring near the end of the measurement range. If the end switch is reached during the measuring process, then the measurement will be stopped; the following message will appear on the monitor:

```
Learn mode
ENDSWITCH REACHED ?
```

The computer beeps a warning.

Shortly after the display of this warning, the program branches to the measurement menu of the corresponding measurement mode to repeat measurement.

ANALYSIS MENU

This menu allows you to alter the threshold or choose different measurement points in the same scan. It displays the MEAN and STANDARD DEVIATION results of several measurements. You can print the last measurement with k1 or Statistics with k2. A bad measurement can be rejected with k5.

```
ANALYSIS Menu:RUN or KEYLABEL

N:      1      Result: 3.36um
N:      1
MEAN:   3.361 um
St.Dev: 0.000 um


.....................................
CLEAR = Restart Stats
Reject Rethresh Dist2      Exit
DIST   STATS    AllDISTS   Files
```

After a measurement has been completed, press SHIFT+AUTO to reset the statistics and start an automatic series of measurements similar to the Operator Program. This is also accessible through k8,EXIT.

```
ANALYSIS Menu:RUN or KEYLABEL

N:      5      Result: 3.37um
N:      5
MEAN:   3.361 um
St.Dev: 0.008 um


.....................................
CLEAR = Restart Stats
Reject Rethresh Dist2      Exit
DIST   STATS    AllDISTS   Files
```

Exit also enables you to return to the LEARN MODE.

k4 is the most important option. This allows the storage of this measurement procedure so that it can be recalled for automatic measurement by the OPERATOR Program and the MULTIPLE MEASUREMENT Program.

The Creation of Measurement Files:

Once the individual measurement parameters have been determined (with the intensity profile from a structure measurement), these parameters, as well as the result of the last measurement, can be stored as a measurement data file.

This measurement parameter file can then be recalled in the automatic program OPERATOR for measurement of similar structures.

The measurement parameters of the last measurement carried out in the interactive part of the program will be stored. In detail the following parameters are stored in the measurement data file:

1. Measurement distance

2. Measurement time

3. Objective

4. Smoothing factor of intensity profile

5. Structure-width value of last measurement in Engineering program

6. Threshold value

7. Choice of 100% Level of Background intensity or the maximum value found during the scan

8 & 9. Left and right measuerment positions (intersection point, minimum, maximum or midpoints of structures)

10. Additive measurement-offset constant

11. Multiplicative measurement-offset factor

12. Upper and lower limits as Design Specifications for this structure. These will flag the operator that the measurement is out of these limits.

```
Measurement Files:
A:  Default          B:  80x32%1-2
C:  80X32%1-3        D:  80X32%1-4
E:  80X32%2-3        F:  80X32%2-4
G:  8032M1234        H:  BiLayer23
I:  RESIST-MET       J:  80X20%M123
K:  IBM8020E14       L:  80X32%3-4
M:  IBM5020E23       N:  RSFLDec14
O:  BL5032%E23       P:  8032129
Q:  BL50Cont         R:  8032124
S:  Leitz            T:  POLYII DCP
U:  IBMRES           V:  ContactVIA

Choose Parameter File, Press A - V
Space=Change Name   X=Exit,Menu
```

You now have the possibility of storing the resulting measurement file in one of the 22 files for on the computer cassette. Choose the file you want by typing the letter (A-V) by its name.

Selecting a measurement data file will allow you to either load a measurement file into the Engineering Program or store that procedure in a data file.

The following information appears:

```
Selected name code is B
LOAD or STORE Data?  Type L or S,
Then ENDLINE (or M=Menu)
?
```

Each measurement file should have its own name, and the following procedure allows you to change the names.

Press SPACE BAR, the computer asks you to type the letter of the measurement file to be changed.

```
Change Code ?
 V
```

After the measurement file has been selected, the desired code of the measurement parameter set must be entered:

```
ContactVIA to ?
POLYII dc
```

The system accepts this new name, and the new catalog of measurement files is displayed:

```
Measurment Files:
A:  Default              B:  80X32%1-2
C:  80X32%1-3            D:  80X32%1-4
E:  80X32%2-3            F:  80X32%2-4
G:  8032M1234            H:  BiLayer23
I:  RESIST-MET           J:  80X20%M123
K:  IBM8020E14           L:  80X32%3-4
M:  IBM5020E23           N:  RSFLDec14
O:  BL5032%E23           P:  8032129
Q:  BL50Cont             R:  8032124
S:  Leitz                T:  POLYII DCP
U:  IBMRes               V:  POLYII dc

Choose Parameter File, Press A   V
Space-Change Name     X-Exit,Menu
```

Pressing key "X" returns the program to the Analysis Menu.

STAGE PATTERN GERNERATION:

Introduction

The MPV-CD with the 517 stage controller comprise a system where the user can generate and store point patterns for locating measurement points on the sample. Through a software DESKEW process errors in placement of the sample, either mechanically or manually, are eliminated.

Deskew process:

When the sample is loaded on to the stage rotational and translational positioning errors are inevitable and detrimental to the operation of a stage positioning system unless steps are taken to compensate. The Leitz system uses two registration points to reference the sample to the stage. These registration points are chosen by the user in such a way that they fall as close to the x-axis and as opposite as possible to increase both accuracy and speed of the deskew process. In operation the stage moves to the approximate location of the first deskew point, and notes this as the relative home position, with this operation the translational errors are mostly eliminated. Upon movement and alignment to the second registration point the rotational errors are then eliminated mathematically.

Beyond this the MPV-CD software supports two stage operation modes:

Normal Stage Operation:

When the system is operating in this mode, distinct points are taught to the system for recall later. The actual coordinates of the points are stored in a file, up to 20 points are possible.

Box Step Operation:

This mode involves relative positioning of the stage referencing to a single distinct point. To calculate this position the user is prompted for the box step in the x and y directions and the number of these steps to be taken. The end result of this is a raster scan of points on the sample. The computer stores the reference point coordinates and the neccessary data for calculating the other measurement points. Up to 400 points are possible in this mode. It is important to remember that while there is the possibility for a large number of points, the points are cannot be randomly programmed.

When the program is selected the program menu is displayed:

```
Stage:X42304 Y32192      000
LOWER END        Pos:20.lum


MPV-CD Stage Pattern Program


Normal Stage Operation
Boxsize                  Exit
Pattern Operate  Loading  CONT
```

Funcition key description:

k1:Pattern

This key allows entrance to the pattern generation mode where the user defines the loading, registration and the measurment points and subsequently stores them.

k2:Operate

Pressing this key enables the user to execute a point file with the possibility of editing previously programmed points.

k3:Loading

This key directs the stage to the loading corner and releases the deskew.

k4:CONT

The function of this key is to toggle between CONTinous and INCRemental stage movement during pointfile execution. The current status of this toggle can be determined from the label of the key on the display. If it is labelled CONT then pressing the key will change operation to CONT, conversely if it is labelled INCR then the current state is CONT and pressing the key will switch to INCR.

k5:Boxsize

Pressing this key allows the user to enter the neccessary data for the boxstep mode. The user is prompted to enter the box size in X and Y, and the number of steps in X and Y. Entering this data automatically puts the program in boxstep mode.

k8:Exit

This key allows for a branch to the exit menu from anywhere in the program. The exit menu then allows various choices including exit back to the main program menu.

PATTERN generation:

Defining a stage pattern is a sequential process where the user led through the process. Automatically, the stage moves to the corner position, which becomes the first reference point. Then the computer begins the stage pattern sequence:

The loading point is defined:

Move to LOADING Point
Using TRACKBALL
and Stage JOYSTICK Buttons
and FAST/SLOW SLEW Button
then press 'STORE POSITION'

The loading point normally is the same as the corner position. It can, however be anywhere within the travel of the stage.

The registration points are defined:

Move to First REGISTRATION Point
Using TRACKBALL
and Stage JOYSTICK Buttons
and FAST/SLOW SLEW Button
then press 'STORE POSITION'

Noramlly the first registration point is located near to the corner for the sake of efficiency of operation. The second registration point is defined in a similar way:

Move to Second REGISTRAT'N Point
Using TRACKBALL
and Stage JOYSTICK Buttons
and FAST/SLOW SLEW Button
then press 'STORE POSITION'

Again the second registration point should be located as directly across from the first registration point on the X axis as possible. The farther apart the greater the accuracy of the Deskew process.

Once the two registration points have been defined, the computer displays:

DESKEWING

and when the process is complete:

DESKEW DONE

Normally the deskew time is short, less than 4 seconds, but it is very dependent upon the relationship of the registration points to each other.

The sequence continues now with the definition of the measurement points:

```
Stage:XØ        YØ          ØØØ
IN FOCUS                 Pos:2Øum

Move to MEASUREMENT Point 1
Using TRACKBALL
and Stage JOYSTICK Buttons
and FAST/SLOW SLEW Button
then press  'STORE POSITION'


                                 Exit
Endpoint
```

In the manner used in the definition of the registration points the stage is manually positioned to the measuremnt point and the position is recorded when the STORE POSITION key is pressed. When in the Boxstep mode this is the only point that is defined. The convention that is used in the computation of the measurement points requires that this point be set in such a way that the box size increments are positive in both X and Y. Which means that then expected raster scan will occur in the first Cartesian quadrant (upper right). When this point is defined, the stage pattern definition is then complete.

For normal stage operation this routine repeats either until the 2Ø point limit is reached or k1:Endpoint is pressed.

Storing Point file:

When finally the point file is created, the computer asks for the name of that point file:

The LOAD, First and Second
REGISTRATION Points, and x
Measuring Points are located
and can be stored in a data
file
Type the name of the file in
6 characters, the 'ENDLINE'
(or just'ENDLINE' to EXIT)
?

With the input of the filename the computer checks to see it there is a compatability problem with an existing file then the message appears:

Choose another filename

After succesful storage of the point file the program returns to the operation menu.

OPERATE:

This routine is accessed by pressing the k2 function key on the HP-85 keyboard. This enables the user to execute a point file in the same manner as the Automatic Stage Measurement Program.

First it is neccessary to load a stored point file. Thus the computer prompts with:

The LOAD, First and Second
REGISTRATION Points, and x
Measuring Points are stored
data file
Type the name of the file in
6 characters, the 'ENDLINE'
ENDLINE=
(or just'ENDLINE' to EXIT)
?

By simply pressing ENDLINE the file that was most recently accesed either by storing or retrieving will be called. If there is no matching filename in the directory then the error meassage will be shown:

FILENAME not in CAT

and the computer will again prompt for filename input.

Once the point file is loaded the sequence follows that same as with the pattern generation except that the computer moves to the predetermined coordinates of the Loading position, Registration points, and the actual Measurement points:

GOING TO LOADING POSITION

Once the stage is in the predetermined loading position, the computer will then prompt:

LOAD OBJECT
then press STORE POSITION

The stage will then move to the first registration point and prompt :

STAGE IS AT FIRST REGISTRATION
POINT, align with JOYSTICK KEYS
or TRACKBALL then press STORE POSITION

When executing this procedure it is very important to approach the alignment mark form the same direction, this eliminates the effect of backlash in the stage mechanism and enables greater positioning accuracy. The stage will now proceed to the programmed points. If the program is in the continuous mode then there will be a two second dwell then it will move to the next point. In the incremental mode the stage will stop at each point and display:

Stage is now at Point 3
Use JOYSTICK keys or TRACKBALL
to edit then press
STORE POSITION

Editing is an automatic process. If the STORE POSITION key is pressed without changing the position then the computer will not update the file. If however changnes are made the computer will ask for a new filename, if the current filename is inputted then the edited version will be overwritten on top of the old data. Using this feature programs can be loaded and modified without the necessity of reprogramming the entire file.

Box Step Pattern Generation:

To set the system to operate in the Box Step mode the box coordinates are inputted by pressing **Boxsize**, causing the following to appear:

Type Delta X(um), then ENDLINE
2300
Type # of Measurements in X, then ENDLINE
10
Type Delta Y(um), then ENDINE
2310
Type # of Measurements in Y, then ENDLINE
10

In the above example the stage will position at 100 (10 in X and 10 in Y) points over a grid 23000 by 23100 um. With this input the system is now ready to accept a Box Step stage pattern.

When the system returns to the main menu it will display the box coordinates and the mode:

Stage:X42304 Y32192 000
LOWER END Pos:20.1um

MPV-CD Stage Pattern Program

Box:X#10 D2300um Y#10 D2310um
Boxsize Exit
Pattern Operate Loading CONT

Pressing PATTERN will enter the pattern generation routine just as with the Normal Stage Operation pattern generation including loading point and registration points. The only difference is that only one point is programmed. This single point is the starting point for the box. The positions will be calculated using the box data using this single deskewed coordinate as a reference. Normally this point is in the 'lower left hand corner' of the stage if the delta X and Y values are inputted as positive. The convention of the stage coordinates is similar to a cartesian system where Y is up (+) and down (-) and the X is left (-) and right (+). The quadrants being numbered counter clockwise starting with +X,+Y as number 1. In the example delta X and Y are both positive, therefore the stage will postition in the first

quadrant relative to this single stage point.

After the single point is stored the porgram will automatically jump to the file storage routine where the file is named and stored on disk.

This program tests the microscope and photometer components. The image of a blank or clear field is scanned and evenness of illumination is checked.

To attain evenness of illumination, the lamp filament must be centered and properly focused to the plane of the condenser aperture, the condenser aperture must be centered and the optical components must be clean.

This program starts with the following display:

```
IN FOCUS                    Pos. 34.8um

Move stage to empty field

Adjust optics and photometer
to value between 700 to 800

Start adjustment with k2 (LIGHT)
  and then press k1 (MEAS) or RUN
Focus ON/OFF=+          Defocus=-
-----------------------------------
                                EXIT
Measure   Light   RotateL   RotateR
```

In accordance with the displayed instructions, the stage must be moved to an empty or clear field, and the light value adjusted to a value between 700 and 900.

The upper line of the display shows the position relative to its range of travel. The units are in absolute dimensions in the intermediate image plane.

To check the photometer's light value press k3 (TEST) or ROLL. The following is displayed:

```
L I G H T   C O N T R O L

If ready press k3, ROLL or [P]
Auto-adjust press SPACE or [#]
793
##########################
```

The decimal value of the light value is displayed, along with a line proportional to the value. The slit, which has been driven to its longest length, is invisible during the light test.

If the system is equipped with an automatically adjustable lamp power supply, press SPACEBAR to automatically adjust the light value to 800.

If the level exceeds 1023, the computer beeps and lowers the lamp current. If the light level cannot be adjusted low enough, the following message is displayed:

DECREMENT GAIN

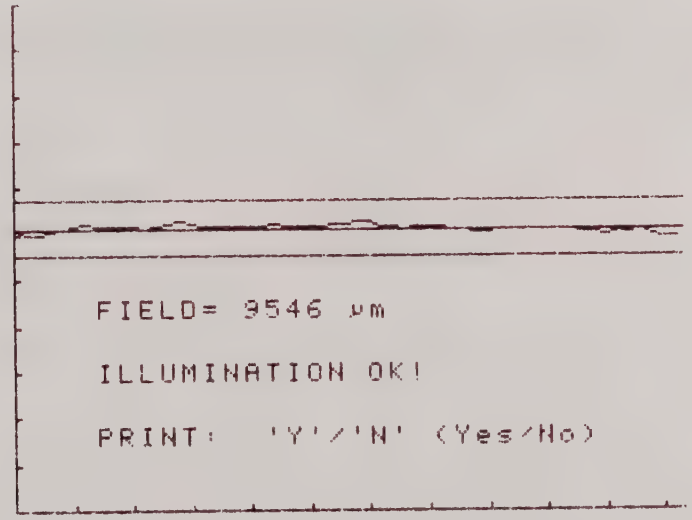
If the light level is too low, the following message appears:

INCREMENT GAIN

The best light value may also be attained by adjusting the gain or high voltage to the photometer.

After adjusting the light value, press ENDLINE to return to the menu.

The microscope is tested for evenness of illumination by pressing k1 (MEASUREMENT) or RUN. The whole measurement field is travelled while the light is being measured. The Graphic profile which results assures you that the light level is even from one side to the other. When satisfactory illumination exists, a graph of the following form will result:



Two lines are drawn across the profile representing +/- 10%.

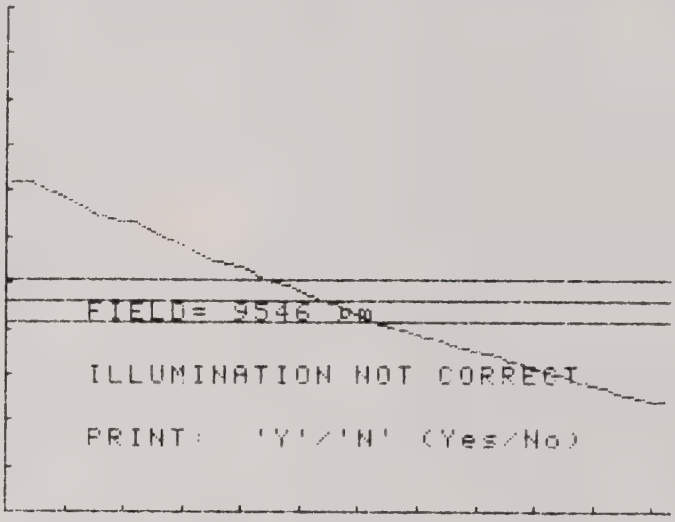
For a printout of the graph, press "Y".

After this decision, the operator may repeat the test by answering "Y" to the question "More Tests?"

If the illumination scan is incorrect, then the graph appears for three seconds along with the words "Illumination Not Correct". The program returns to the measurement menu for a new

adjustment and repetition of the measurement.

If the selected light value is too low or too high, the measurement is stopped and the following message is displayed:



To stop the testing procedure at any time, press k8 (EXIT). The system returns to the Program Menu.

PITCH CALIBRATION PROGRAM

The CALIBRATION Program allows the full flexibility of the system to be utilized in setting up the calibration to a standard. This standard is measured by putting in the standard distance (a pitch).

There are two menus in this program. Pressing KEYLABEL rotates these in order. Pressing RUN at any time starts a calibration scan with the current parameters. The system is operated primarily by the eight SPECIAL FUNCTION KEYS below CRT. The bottom row on the CRT are four labels for keys k1 to k4. The second row on the CRT label keys k5 to k8. Press the SHIFT key, then the function key needed.

Leitz MPV-CD Program Loading

PRE-RUN MENU

Current system values are displayed. Change any value by pressing the appropriate Function key.

```
Push DISPLAY Keys to alter Value
Push COPY to Print Display
Objective          :  80 X
Standard           :  9.02 um
Smooth             :  4
Speed              :  3 secs
Threshold          :  32%
100% Thres.        :  Background
CALIBRATION DATA,INFORMATION
#1232GpitchNov1

Meter/in CAL,DATA OBJECTIVE Exit
Threshold  STANDARD  Smooth  Speed
```

k1. The MEASUREMENT THRESHOLD is displayed as default value for an endline question. Limits are 1 to 99. The setting of the 100% threshold has two alternatives. MAXIMUM averages around the brightest part of the scan is a universal setting, and must be used for bright lines. BACKGROUND averages the first part of the scan to set the 100% level; this can be used for dark lines or lines of low contrast.

k2. The stated dimension of the pitch standard to be scanned is needed. This STANDARD is multiplied by 1.2 and rounded up to a unit of distance to determine the travel distance.

k3. Type a value of SMOOTHING. This is a moving average of the 1000 data points and helps to eliminate electronic noise and vibration. The value is the number of repetitions of a simple 2-value moving average. Limits are 0 to 99.

k4. Type the duration of the scan in seconds. Limits are 1 and 20. The speed and travel are evaluated by the computer and, if not correct, the question is asked again.

k5. This determines the units of measure, metric or inch.

k6. Standard name allows the entry of a line of 32 characters.

k7. This tells the system a particular objective is to be calibrated.

k8. This is a general exit from the calibration process and can branch back to continue measurement, store the current calibration but stay in the calibration program, or go to the program menu.

```
CURRENT STANDARD:
#842JpitchJul1

Type NEW NAME, then ENDLINE
  or ENDLINE (32 characters)
?
#1232GpitchNov1
```

RUN MENU

This menu allows adjustment and alignment of the slit to the structure. The four cursor control keys are now active for this step. Up-Arrow lengthens the slit; Down-Arrow shortens it. Right-Arrow moves the slit in the direction of the scan and Left-Arrow moves it backward. (These can be used when the slit is horizontal to test the direction of the scan.) Use k3 and k4 to Rotate slit (over 200 degrees). Note you can measure from left-to-right, top-to-bottom, bottom-to-top, or any orientation in between.

```
IN FOCUS                Pos:  40.31 um
RUN Menu:Push RUN or KEYLABEL
LEFT, RIGHT ARROWS to move slit
UP,DOWN ARROWS to change length
CALIBRATION


                                  Exit
Meas. Light     RotateL         RotateR
```

1. Use these controls to align the slit to the standard edge. Lengthen it to maximum. Move it to the edge (on a dark line next to a bright edge is easiest). Rotate until the two are parallel. Shorten slit to a length suitable to the structure. A suggested slit length is one in the middle of possible lengths, step 4 or 5. A longer slit aperture can be used on granular surfaces to ignore the effects of particle boundaries, or on jagged edges to average out this effect.

2. Before a calibration scan can be started, the photometer's signal should be checked. During a measurement this signal should remain within a range of 200 to 1023. The target value of 800 should be used if possible.

To check the photometer's signal, move the measuring slit to the brightest spot of the structure to be investigated. Press k3 (TEST). The following printout appears on the monitor:

```
If ready press          END LINE
Auto-adjust press       SPACEBAR

808
##############################
```

In the line above the bar (to the left) is the photometer's measured value. The length of the bar is proportional to this value.

If the measuring system is equipped with an adjustable stabilized power unit, an automatic adjustment of the illumination level is thus possible.

After pressing of the SPACEBAR the level of illumination is changed until a photometer signal value of approximately 800 results. Should the illumination level exceed 1000 or fall below 400, a warning is displayed.

```
If ready press          END LINE
Auto-adjust press       SPACEBAR
INCREMENT GAIN
1023
##################################
```

The desired photometer signal value is also obtained by setting the high voltage and/or the photometer gain.

If an automatic adjustment of the illumination level is not available, then manual adjustment of it, of the high voltage and of the photometer gain will achieve the desired photometer signal value.

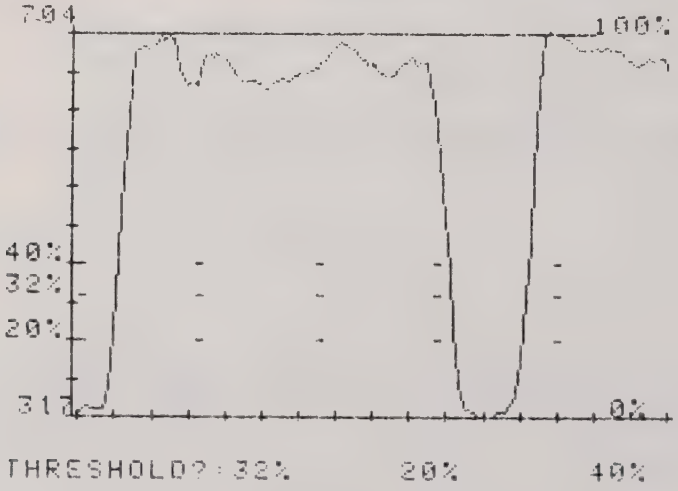
A warning signal sounds when the photometer signal exceeds a value of 1000.

Adjustment of the photometer's signal is completed with ENDLINE.

Move back to the starting position of the measurement scan and press "RUN".

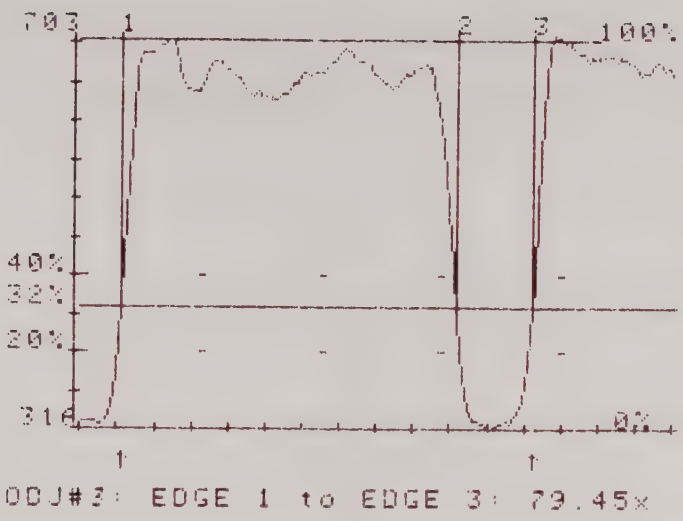
GRAPHICS PROFILE

The image is scanned, and a graphic display of the intensity profile is drawn. Note the scan travel distance is temporarily displayed. The scan can be reRUN immediately if something is incorrect; press KEYLABEL at this time branches to the RUN menu for adjustment. If at any time you want to START from the beginning, or return to the PRE-RUN MENU, or return to the PROGRAM MENU, press k8 and you will be asked where you want to go.



The DETECTION THRESHOLD is drawn across the structure profile. The MEASURING POINTS are labeled at the intersections of the threshold and the profile. Edges very close together may be detected but the labels suppressed if they would be typed on top of each other. Additionally, edges at the extreme start of the scan are ignored.

Press k1 to k4 to choose the mode of measurement for one end of the measurement. Press the number of the EDGE points or the numbers if two points are required. Then press ENDLINE to tell the computer you have made your choices.



Press k1 to k4 again to choose the mode of measurement for the other end of the measured distance, then press ENDLINE to tell the computer you have made your other choice.

For example, press k1 EDGE. Press the number of the edge desired. Then press ENDLINE again to tell the system you have made your choice.

Choice of MINIMUMS, MAXIMUMS, or MIDPOINTS require entry of two points. The calibrated magnification of the objective will be displayed under the graph of the profile. You have the option of printing the graph by pressing SHIFT and COPY.

Press KEYLABEL or SPACEBAR to proceed to the PreRUN menu.

Exit and Storage of Calibration Values:

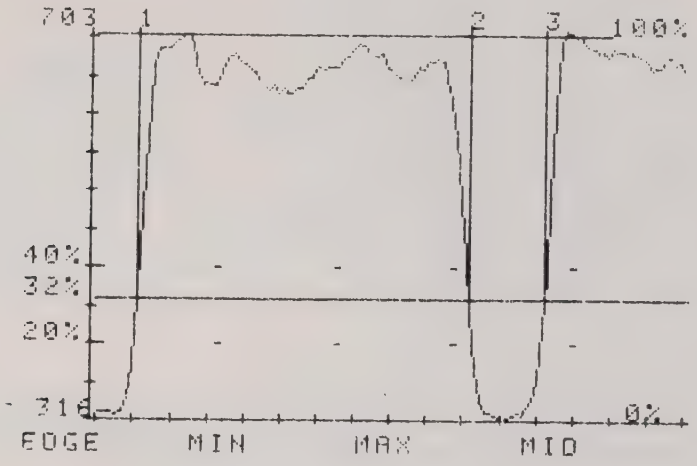
From the PreRUN or RUN menu press k8 (EXIT).

You will be asked whether you want to continue with another objective, store this calibration but stay in the calibration program, or exit to the Main Menu. Store but stay in calibration is used to duplicate the new data on a backup tape. Change tapes, press "S", and when the tape light goes off, switch tapes and exit normally. The normal EXIT TO MAIN MENU will store the calibration.

C = Continue CALIBRATION
S = STORE calibration but return to this menu
P = Return to Program Menu
Type C, S, or P, then ENDLINE
?

A more detailed explanation follows.

The measurement positions can be either the intersection points of the intensity profile with the threshold, the midpoints of these intersection points or also the minimums or maximums between these intersection points (see also graph below).



An explanation of the individual keys follows:

k1. Type of measurement chosen is with an intersection point (EDGE). After selection of this kind of measurement, the number of the chosen intersection point must be entered.

k2. Type of measurement chosen is with a minimum (MIN). The minimum is between two intersection points that are to be entered.

k3. Type of measurement chosen is with a maximum (MAX). The maximum is between two intersection points that are to be entered.

k4. Type of measurement chosen is calculated as the midpoint between the two selected points. This can be used for a midpoints pitch of two lines, a pitch based on the midpoints of the defraction lines.

Standard pitch is determined in the following manner:

1. Selection of the type of measurement to be used for the first measurement position by depression of key k1-k4.

2. Input of the desired intersection-point (1-9) or of the desired intersection-point combination (1-9) and completion of entry for this measurement position with ENDLINE. A correction of the intersection-point choice is possible before completion of the entry via BACK SPACE key.

3. Selection of the type of measurement to be used for the second measurement position by pressing of key k1-k4.

4. Input of the desired intersection-point or intersection-point combination corresponding to point 2.

5. Completion of standard pitch calculation by pressing END-LINE.

In the following example the center-to-center distance of two chrome lines on a mask was determined according to the above procedure.

For the first measurement position "MID", "1", "2" and END-LINE are entered in the order given, for the second position "MID", "3", "4" and ENDLINE. The following printout appears on the monitor:

When ENDLINE is pressed again, the graph is displayed with the calibration result.

Sources for Error:

Before starting measurement the program checks the entered measurement parameters, such as objective magnification, measurement time, and standard value.

If no objective magnification was assigned to the code number entered, the following is displayed on the monitor:

```
OBJECTIVE not Used,Calibrated
Enter Nominal Magnification,
Then ENDLINE
?
```

When the combination of parameters entered is incorrect, the following comment, accompanied by a beep, is displayed on the monitor:

LINEWIDTH GREATER THAN FIELD

or

SPEED ERROR

and the program returns to start for re-input of the measurement parameters.

Another error can occur when measuring near the end of the measurement range. If the end switch is reached during the measuring process, then the measurement will be stopped; the following message will appear on the monitor:

ENDSWITCH REACHED ?

The computer beeps a warning.

Shortly after the display of this warning, the program branches to the measurement menu of the corresponding measurement mode to repeat measurement.

THRESHOLD CALIBRATION PROGRAM:

The threshold calibration serves to calibrate the system with the aid of a reference standard.

For some applications the edge detection threshold is best defined by threshold measurements on a reference structure. A calibrated standard or sample which has been measured by a SEM may be used to calibrate the MPV-CD.

This calibration is essentially a measurement in reverse; the MPV-CD is told what the linewidth is for the standard or sample and the system tells at what threshold this linewidth is found. This kind of calibration is performed by searching for a threshold value.

Another possibility is calibration to a reference structure using a corrective offset. The calibration offset is introduced to the system in the Engineering Program. With offset calibration the nominal structure-width is attained by adding a constant value to the measurement result and/or multiplying this measured value by a constant factor.

Determining the Mesurement Parameters:

In this section the necessary measurement parameters are entered. Always complete your entry with ENDLINE.

After the program has been loaded and initialized, the display below appears on the monitor:

Leitz CD CALIBRATION Program
CALSTR

for calibrating the unit with
a reference structure

Ref structure identification
LEITZ1?

The operator has the possibility of entering a NAME for the reference standard. The maximum length of the standard's name may not exceed 16 characters. The name of the standard previously used may be kept by pressing ENDLINE.

The STANDARD's width is entered next. The width of the standard used last, that of 10.00 micrometer, is displayed. We enter the standard's width of 4.50 micrometer:

Structure nom. width 5.33 um?

The objective magnification is entered next. The operator enters the desired objective code number according to the system's data. We choose the objective 80x:

```
Which objective# ? 3
Obj # 3                    80 x
```

If the objective chosen is not calibrated, the following is displayed:

```
Which objective# ? 1
OBJECTIVE NOT CAL !
```

and the program returns to allow redetermination of the objective's magnification.

With the entry the measurement time is determined. It can be from 1 to 9 seconds. The operator is offered the present measurement time or, when available, the time previously used--in this case 2 seconds.

We choose a measurement time of 3 seconds:

```
Please enter scan time
(1. . .9 sec per structure) 2 ?
2 sec
```

Measurement Preparations:

Upon completion of these entries, the system is ready for measurement. The monitor displays the measurement menu which contains information concerning adjustment of the measuring slit in reference to the object's structure.

```
LOWER END                  Pos. 35.35 um
                    *

Please adjust measuring slit to
  the LEFT of the
  REFERENCE STRUCTURE
The slit should be SHORTER than
  the width
The slit should be PARALLEL to
  the edge
--------------------------------
                           EXIT
MEASURE   Test   RotateL   RotateR
```

This adjustment of the measuring slit to the object's structure is executed using the following keys:

HP 85 Key	Function
	Lengthening of measuring slit
	Shortening of measuring slit
	Measuring slit moves to left
	Measuring slit moves to right

Furthermore, the measuring slit's position (in reference to an end of the travel range and to the object) is indicated in the uppermost line. In addition the relative measuring-slit position is marked by the position of an asterisk "*" in the second line.

Measurements should not be started until the photometer's signal has been checked. During a measurement this signal must remain within the range of reception,and the available intensity resolution (max. 1024 intensity value increments) should, when possible, be fully utilized.

To check the photometer's signal, move the measuring slit to the brightest spot of the structure to be investigated. Press k3 (TEST) or ROLL. The following display will appear on the monitor:

```
If ready press          END LINE
Auto-adjust press       SPACEBAR
801
##############################
```

In the line above the bar (to the left) is the photometer's measured value. The length of the bar is proportional to this value.

If the measuring system is equipped with an adjustable stabilized power unit for object illumination, then an automatic adjustment of the illumination level can be executed.

After pressing of the SPACEBAR the level of illumination is changed until a photometer value of 800 results. Should the illumination level exceed or fall below the limit value, a corresponding warning is displayed on the monitor:

```
If ready press          END LINE
Auto-adjust press       SPACEBAR
INCREMENT GAIN
```

or

```
If ready press          END LINE
Auto-adjust press       SPACEBAR
DECREMENT GAIN
```

The optimal photometer signal value is also attained by setting the high voltage and/or the photometer amplification.

If an automatic adjustment of the illumination level is not possible, then manual adjustment of it, the high voltage and of the photometer amplification will set the desired photometer signal value.

A warning signal sounds when the photometer's signal exceeds a value of 1000.

Adjustment of the photometer's signal is completed with END LINE.

Calibration Measurement:

After completion of the measurement preparation, the actual calibration measurement can be started by pressing k1 (MEASUREMENT) or RUN.

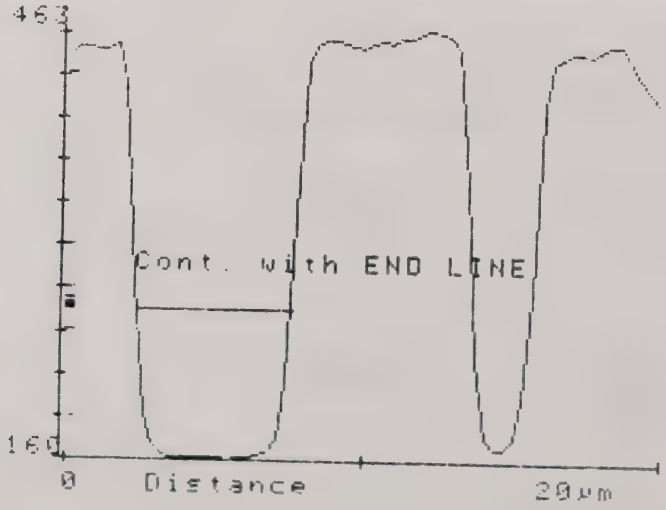
Caution! To avoid causing vibrations during the measurement process, do not touch the microscope. A reminder is displayed on the monitor:

PLEASE DONT TOUCH THE MICROSCOPE
START MEASUREMENT

WAIT FOR A BEEP

The end of the measurement procedures is indicated by a beep.

Ifnoerrorswere made during inputofthemeasurement parameters and positioning of the slit (see next selection), and if, moreover, the measured structure width, in the 15% to 65% range of the intensity profile, is the same as the nominal structure width, then the following graph will appear on the monitor:



Should the measured structure width in the above mentioned range not be equal to the nominal structure width, the intensity profile will be displayed for a short time on the monitor, to be then replaced with the following comment:

INPUT ERROR

A warning signal sounds concurrent with this error display, and the program returns to start for re-entry of the measurement parameters.

The measured threshold will be displayed when you press ENDLINE. The value in question will then appear on the monitor:

Threshold = 28.9 %

Accepted: 'Y'/'N' (Yes/No)

If satisfied with this value, the operator must press "Y" (Yes), otherwise the key "N" (No).

With "Y" the program is stopped; with "N" the operator can manually enter a threshold value or repeat the calibration:

Threshold = 29.2 %

Accepted: 'Y'/'N' (Yes/No)

SET Threshold 'S'
NEW New Measurement 'N'

To manually enter a threshold value, the "S" (Set) key must be pressed. The following test is then displayed on the monitor:

Enter threshold
?

Press ENDLINE to tell the computer you have typed the new threshold value.

In order to perform additional calibration measurement, "N" (New Measurement) must be pressed instead of "S". The program then returns to start for re-establishment of the measuring parameters.

To return to the MAIN MENU of Programs press k8 (EXIT).

INSTRUCTIONS FOR INITIAL START

I. Hardware

A. Microscope Stand

1. Microscope must be on Vibration-Isolation Table (or Base 543-Ø43).

2. Power line must be stable and free of electrical static. (Do not plug stabilized lamp power supply into a line filter.)

3. Check that Photometer column is securely attached to prism block.

4. Check that prism block is securely attached to microscope stand.

5. Look through top lamphouse port to check cleanliness of swingout lens. Check both sides.

6. Look in cutout on left side of stand where slit inserts. Check cleanliness of top and bottom dust glass covers in this opening.

7. Check cleanliness of dust glass on top of Photometer column.

8. Check electronic connector on top of Photometer column.

9. Install Photometer housing, ensuring that the electronic connectors mate properly. Tighten 3 Allen screws. (Do not expose Photomultiplier tube to direct light, especially not while power in on.)

10. Filter or filter adapter must seat fully in opening at top of column. This pushes a spring-loaded dark flap out of the way.

11. Check top and bottom glass covers in slit mechanism for cleanliness. Use only gas to remove dust or swab to remove fingerprint.

12. Insert slit mechanism into stand and tighten set screws on right side of stand.

13. The dust glasses on the top and bottom of the prism block located below the FSA tube and above the vertical illuminator) must be clean.

14. Beam splitter knob should be in middle position (50%-50%.

15. Check condenser lens and mirror in lamphouse must be clean, and all axes of movement must be free.

16. Clean and prelevel wafer-holder or glass stage plate.

17. Turn coarse focus to middle of range.

18. Install stage. Insert light shield.

19. Check cleanliness of top and back lenses of vertical illuminator. Dichroic beamsplitter inside must be free of dust. Use only gas to gently blow dust. No lens cleaner, no swabs!

20. Insert vertical illuminator and tighten set screw on right side.

21. Clean FSA tube and install.

22. Clean eyepieces and set their manual focus to the line scribed on the eyepiece barrel.

23. Clean the objectives with a freshly broken piece of styrofoam. Screw into illuminator securely. Check front cap of objective.

24. Lift stage on focusing block until sample is about one millimeter below the 80x objective. Use coarse focus knob to bring sample into focus. This is for optical alignment; laser autofocus will be adjusted later.

25. Plug in lamp power supply (set to manual control). Turn on lamp.

26. Focus on bright surface of sample using 80x objective.

27. Using focusing telescope, make sure that the preset pinhole apertures are centered!!

28. With largest aperture in place, use focusing telescope to align and focus the lamp filament. The filament should be superimposed on the mirror image. They both should be in focus in the same plane as the condenser aperture. Focusing telescope may be removed.

29. Move stage in one axis and rotate eyepiece with reticle until crosshair is orthogonal to stage movement. Pressure tabs of the FSA tube which hold the eyepieces in place should be adjusted so that the eyepieces do not rotate when their manual focus adjustments are made.

30. Adjust the manual focus of each eyepiece until the slit is in focus. (Reticle should also be in focus.)

B. MPV-CD ELECTRONIC CONSOLE

1. Inspect all cables to insure proper connection. Cards should be fully seated in the card cage. Fuses and internal connectors may have to be checked.

2. Connect grounding cable from microscope to electronic console.

3. Set rear toggle switch to INTERNAL.

4. Set front toggle switch to STAT.

5. Set toggle switch on bottom of Photometer housing to the circle position (to rear).

6. Set FILTER to 10.

7. Set GAIN to 4.

8. Set Io dark current compensater to 0, counter-clockwise.

9. Set HIGH VOLTAGE for photomultiplier range 000 to 250.

10. If equipped with LEITZ LASER AUTOFOCUS: Inspect cable connections from vertical illuminator to focus motor and cable from focus motor to electronic console. Adjust COARSE FOCUS according to LAF Section. There must be at least one millimeter space between the objective and the sample.

11. Set SLIT-APERTURE Light to MAXIMUM (clockwise).

12. Set POWER rocker switch to ON.

13. The electronic console tests itself for proper function, drives the slit to the longest length, drives it left to right and back to the center of the image. If equipped with AUTOFOCUS, the FINE FOCUS is driven down to the LOWER END of focus travel (about one millimeter).

C. LAMP POWER SUPPLY

1. If HP model, set METER to 12 AMPS. Turn ON>

2. If 576 model, set Selector to ANALOG. Turn ON.

3. For manual control:

HP model: Disconnect cable from electronic console.
576 model: Set Selector to Manual.

D. MOTORIZED STAGE CONTROLLER: 517-CD Model

1. Inspect cable connections to stage (RED, BLUE) and 25-pin connector on rear of controller.

2. If manually controlled, set COMPUTER/LOCAL to LOCAL. Turn ON.

3. If computer controlled, inspect IEEE488 cable at center of rear of controller to HP85.

4. See 517 Stage Controller Instructions. Note JOYSTICK, SLEW/STEP, FAST/SLOW, HOME, and MASTER RESET (DEFINE HOME).

E. FLOPPY DISK DRIVE Mass Storage Device

1. Inspect HPIB cable to insure the green plug is fully inserted into HP85.

2. Open front door.

3. Set POWER rocker switch on front of DISK DRIVE to ON. The HP85 computer must be turned on last.

4. After front light goes on and off (about one second), carefully insert floppy disk.

5. Close front door softly.

F. HP85 MICROCOMPUTER

1. Inspect INTERFACE plugs at rear of HP85 by gently rocking from side to side as you push in.

2. Insert TAPE cartridge. Record tab on cartridge must be in record position.

3. Set POWER rocker switch at right rear to ON. Program loads automatically.

G. LEITZ LASER AUTOFOCUS

1. When turned on, the electronic console will automatically reset the FINE FOCUS to the LOWER END of focus travel. The MPV-CD Computer Programs thus assume that the sample is at the LOWER END (DEFOCUSED position). The COARSE FOCUS of the METALLOPLAN MICROSCOPE, if at either end of its range of travel, will physically block the travel of the fine focus. This will lock the electronic console in its self-test. Adjust the stage as follows.

2. Turn on the electronic console; this will drive the FINE FOCUS to the LOWER END.

3. Adjust COARSE FOCUS to the middle of its travel.

4. Adjust the mounting of the STAGE on the MICROSCOPE until a typical sample is located OVER ONE MILLIMETER below OBJECTIVE. Lock stage tightly on microscope.

5. When the MPV-CD Computer Programs are running, the autofocus is controlled by four keys. Hold down the "/" key until the FINE FOCUS is driven up until it stops at the UPPER END of STAGE TRAVEL (a few seconds). This control starts slow and accelerates. You should watch the FINE FOCUS knob to see it turn and stop, and watch the OBJECTIVE so that the sample is not damaged.

6. With the FINE FOCUS at the UPPER END of travel, adjust the COARSE FOCUS so that this upper limit of travel is ABOVE the image focal plane yet BELOW the OBJECTIVE.

7. Press the "-" key. This will drive the stage down to the LOWER END of FINE FOCUS travel.

8. Press the "+" key. This will drive the stage up to the focal plane for that sample, objective, and focus offset. STEP SIX sets the UPPER LIMIT of FOCUS travel above the sample focal plane, yet below the objective. If for some electronic reason the autofocus does not find the focal plane, this upper limit will prevent crashing into the objective.

An alternative way of setting the autofocus travel is to adjust the microscope so that the focal plane is in the middle of the range of focus travel. This will disable the crash protection feature of the upper limit switch but allow for much greater variation in the altitude of the focal surface. This is a commonly used configuration in the manufacture of magnetic disc heads.

1. When turned on, the electronic console will automatically reset the FINE FOCUS to the LOWER END of focus travel. The MPV-CD Computer Programs thus assume that the sample is at the LOWER END (DEFOCUSED position). The COARSE FOCUS of the METALLOPLAN MICROSCOPE, if at either end of its range of travel, will physically block the travel of the fine focus. This will lock the electronic console in its self-test. Adjust the stage as follows.

2. Turn on the electronic console; this will drive the FINE FOCUS to the LOWER END.

3. Adjust COARSE FOCUS to the middle of its travel.

4. Adjust the FINE FOCUS to the middle of its range of travel. This is five turns of the focus knob up from the lower limit of travel.

5. Adjust the mounting of the STAGE on the MICROSCOPE until a typical sample is located LESS THAN ONE MILLIMETER below OBJECTIVE. Lock stage tightly on microscope.

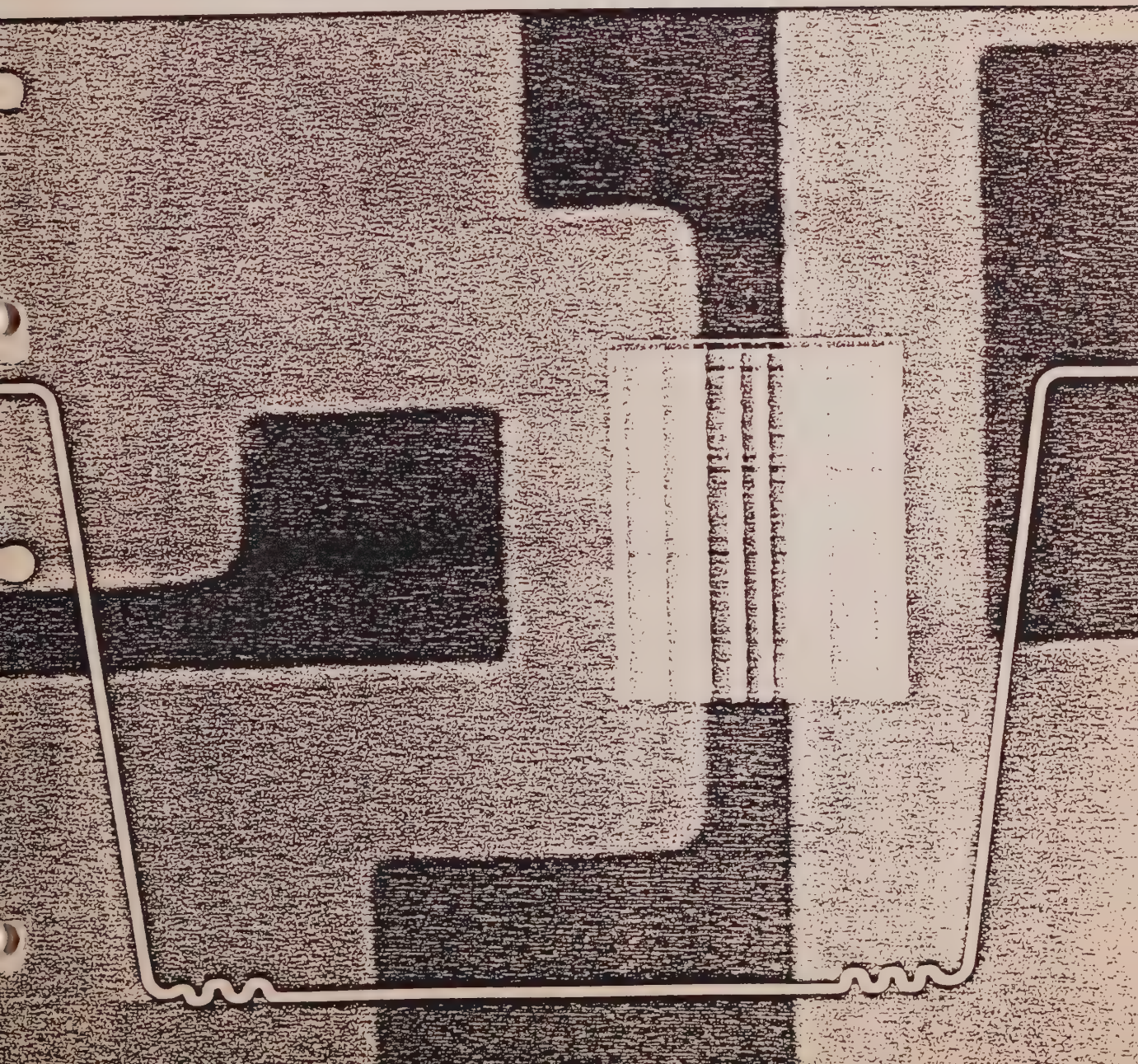
6. Adjust the COARSE FOCUS again so that the sample is in focus.

7. When the MPV-CD Computer Programs are running, the autofocus is controlled by four keys. Press the "-" key. This will drive the stage down to the LOWER END of FINE FOCUS travel.

8. Press the "+" key. This will drive the stage up to the focal plane for that sample, objective, and focus offset. STEP SIX sets this focal plane in the middle of the range of fine focus travel. This has disabled the protection feature of the upper limit switch, but reduced the possibility of touching the limit-switch in normal operation on samples with large variations in height of the focal surface.

LEITZ MPV CD

Instruction Manual Software



S E M C A 3

Operator's Manual for

Software Package of the

Photometric Linewidth Measuring System

MPV-CD

Version 3.1

Mai 1983

Ernst Leitz Wetzlar GmbH

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1. Preparation of the Measuring System and General Information

1.1 Automatic Test

The instrument must be completely set up and all connections correctly performed. The enclosed program cassette is to be inserted into the appropriate slot of HP 85 and the system switched on. Once switched on the computer automatically starts a test routine which checks if all the connecting leads are joined and all components (control unit, lamp power supply unit) switched on.

If defects are determined, the following appears on the HP 85 monitor:

```
MPV - C D  Program  V3.0 TAPE

copyright ERNST LEITZ GmbH

1.9.82 Peter Ast Wetzlar

Is the system on power and are
all components connected
together ?
Check and start again
```

Please recheck all connections, switch off HP 85 and switch it on again.

Besides checking if the connecting leads are joined and the components switched on, the system also tests the dialoque exchange between the desk computer and the control unit. If defects in the dialogue are determined, the following appears on the monitor:

```
Eprom# :301305.406007407007V1.0

Bin Prom: CD 2.4 DEC 08/81
```

If the dialogue was trouble-free, the momentary EPROM number and the code number of the binary program appear on the monitor:

Eprom# :301305.405007407007V1.0
not correct

These print-outs contain important information for the service technician.

An additional check within this automatic test routine concerns the measuring-slit mechanism. The system exactly moves the measuring slit from one end of the travel range to its center. If the measuring slit can be exactly positioned, the following is displayed on the monitor:

POS= 5000

and the system has concluded the automatic test.

If such is not the case, the attained measuring-slit position together with the comment "RESET" will be indicated and the automatic test routine repeated until the measuring slit has been satisfactorily positioned.

The system's checking procedures take approx. 1-2 minutes.

1.2 Establishing the System Parameters

If no errors are determined by the system's check, the system responds by displaying the following information on the monitor:

```
SYSTEM PARAMETERS
1..Objective # 1..  16 x   cal
2..Objective # 2..  32 x uncal
3..Objective # 3..  80 x   cal
4..Objective # 4.. 100 x uncal
5..Objective # 5.. 160 x uncal
6..Rev Factor ....   0.80 x
7..Tub  Factor ...   1.55 x
8..Unit Identific.   MPV-CD 1
9..Supervisor.....   A. Mueller
10.Date...........   1.9.1982
11.Operator.......   W. Schmitt

SOME CHANGES NECESSARY? IF YES,
ENTER  LINE#  ?
```

These are the essential system parameters, such as choice and state of the objectives, the revolving nosepiece, the measuring tube, the system's identification, the date and the identification of the supervisor and operator.

Important:

Every system has its own cassette, and only it is to be used with that system; all important data for the system are stored in its cassette. Exchanging the objectives without recalibrating or using the system cassette on another instrument can lead to major measured-value discrepencies.

When a change is required, for example the exchange of an objective, the corresponding number is to be typed in. If we wanted to replace objective 16X with objective 8X, the input (corresponding to the print-out below) would read:

```
1
new Objective # 1 is:
?
8
```

The new objective value appears afterwards in the system's amended identification. For the system the objective is not calibrated at present.

```
SYSTEM PARAMETERS
1..Objective # 1..   8 x uncal
2..Objective # 2..  32 x uncal
3..Objective # 3..  80 x   cal
4..Objective # 4..100 x uncal
5..Objective # 5..160 x uncal
6..Rev Factor ....   0.80 x
7..Tub  Factor ...   1.55 x
8..Unit Identific.   MPV-CD 1
9..Supervisor.....   A. Mueller
10.Date...........   1.9.1982
11.Operator.......   W. Schmitt

SOME CHANGES NECESSARY? IF YES,
ENTER  LINE#  ?
```

When either the nosepiece or the measuring tube is exchanged, a recalibration of all objectives is necessary. If, for example, the nosepiece 0.8X is exchanged with one of magnification 1.0X, then the following input and output occurs:

```
6
enter new revolver factor?
1

SYSTEM PARAMETERS
1..Objective # 1..  16 x uncal
2..Objective # 2..  32 x uncal
3..Objective # 3..  80 x uncal
4..Objective # 4..100 x uncal
5..Objective # 5..160 x uncal
6..Rev Factor ....   1.00 x
7..Tub  Factor ...   1.55 x
8..Unit Identific.   MPV-CD 1
9..Supervisor.....   A. Mueller
10.Date...........   1.9.1982
11.Operator.......   W. Schmitt

SOME CHANGES NECESSARY? IF YES,
ENTER  LINE#  ?
```

This system information can be printed at any time by pressing COPY.

If no further changes are required, simply press END LINE. The system now leaves the initiation program and branches to the program menu as indicated on the monitor:

```
Please enter PROGRAM #

1..ADJUST(helps you adjust the
   microscope and photometer)
2..CALGRT(calibrating the unit
   with a grating-standard)
3..CALSTR(calibrating the unit
   with a reference structure)
4..OPSMEA(simple OPERATOR PROG.
   for STRUCTURE meas.on masks)
5..INTAME(interactive and autom.
   meas. on masks and wafer)
6..OPER(OPERATOR PROGRAM)
7..CHANGE SYSTEM INFORMATION

Please wait for program # 1
```

The desired program is selected from this menu by typing in the corresponding number (in our case the number "1").

Of course it is still possible to change the system's parameters at this point. After the number "7" has been typed in, the program branches to input of the system parameters. The system's identification appears on the monitor, and the system is prepared for changing of its parameters.

1.3 General Information about the System

1.3.1 Accuracy of the Measurement Results

1. The accuracy of the measurement results is determined by the numerical resolution of the measurement distance. Since the total measurement distance is divided into 1,000 increments, the numerical resolution below results:

$$\Delta = W / 1000$$

with

W : Travel distance of measuring slit (in ref. to object) during measurement process

2. The displayed and printed measurement results are rounded off to two digits after the decimal point.

1.3.2 Calibrating Measuring-Slit Movement

After the measuring system has been switched on, a calibration of the measuring slit's movement is automatically executed. During this calibration the measuring slit is driven to its end switches and the position of these hardware end switches is registered; this then serves the system to determine the measuring slit's maximum range of travel. The start of this travel range is established by the system near one of the end-switch positions.

From time to time additional calibrations are automatically performed (even after this first calibration) as described above. After performance of these additional calibrations, the measuring slit returns to its position prior to calibration.

Important!

These system-performed calibrations have no influence on measurement accuracy. After having completed the calibration process, the system immediately returns control of the measuring instrument to the operator.

2. Illumination Homogeneity

The program ADJUST serves to check and set the microscope and photometer components. Especially homogeneous illumination of the microscope image and signal reception of the photometer are checked.

To attain a homogeneous illumination, adjustment of the lamp (see Instructions Lamp Housing) and setting of the Koehler illumination (important with transmitted-light measurements) are required.

After selection of this program the following measurement menu appears on the monitor:

```
                    Pos.:    5001µm
                    *

Move stage to empty field

Adjust optics and photometer
to value between 700 to  900

Start adjustment with K3 (TEST)
or ROLL and then press K1 (MEAS)
or RUN
-------------------------------
                              EXIT
MEASUREMENT          TEST
```

According to these displayed instructions, an empty field must be found in order to measure for homogeneous illumination. The photometer should have a value between 700 and 900.

The uppermost line of the monitor representation shown above indicates the measuring slit's momentary position in the measuring plane (intermediate image plane). In this case the measuring slit's position refers to an end of the travel range. The position of the asterisk * in the second line correlates to this measuring-slit position.

2.1 Checking the Photometer's Signal

To check the photometer's signal press K3 (TEST) or ROLL. The following print-out appears on the monitor:

L I G H T C O N T R O L

If ready press END LINE
Auto-adjust press SPACEBAR

In the line above the bar (to the left) is the photometer's measured value. The measuring slit, which is invisible during this test, is adjusted to its maximum length.
The last line represents a bar whose length is proportional to the photometer's measured value.

If the system is equipped with an adjustable stabilised power unit, an automatic adjustment of the illumination level is then possible. By pressing of the SPACE BAR the level of illumination changes until a photometer value of 800 results.

Should the illumination level exceed or fall below the aforesaid limit value, a corresponding warning is displayed on the monitor:

INCREMENT GAIN

or

DECREMENT GAIN

The optimal photometer signal is also attained by setting the high voltage and/or the photometer amplification.

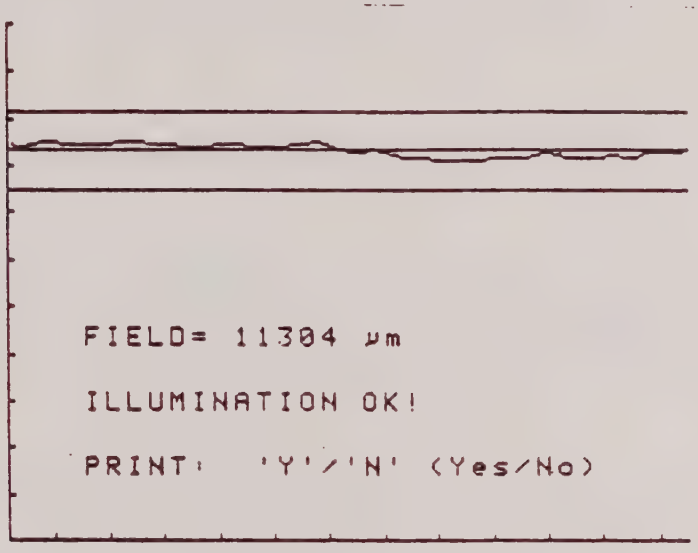
If an automatic adjustment of the illumination level is not possible, then manual adjustment of it, the high voltage and of the photometer amplification will achieve the desired photometer signal.

A warning signal sounds when the photometer's signal exceeds a value of 1,000.

Adjustment procedures for the photometer's signal are completed with END LINE.

2.2 Measuring Illumination Homogeneity

Measurement for homogeneity is begun by pressing K1 (MEASUREMENT) or RUN. The total available measurement field is travelled by the measuring slit, and the intensity is registered. The resulting intensity profile appears on the monitor. When satisfactory illumination of the microscope image exists, a graphic representation of the following form, for example, appears:

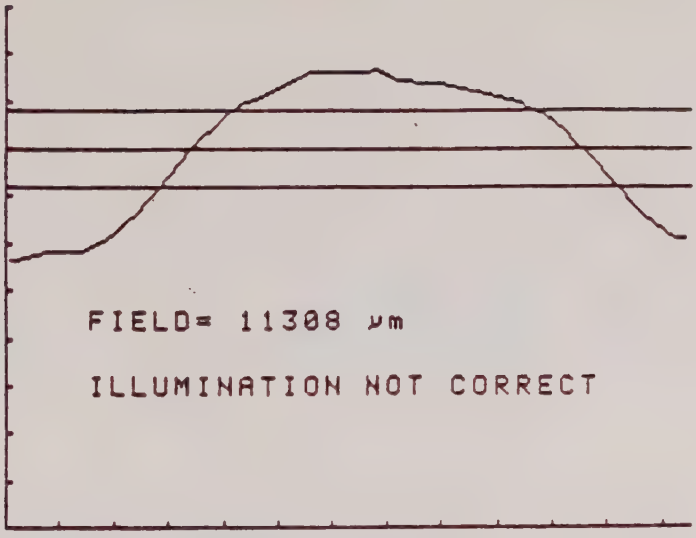


A tolerance of ±10% from the mean value is accepted. For a print-out of the graph, press key "Y" (Yes).

After execution of the command Yes or No, the operator will have the possibility of stopping the program (by pressing "N") or of carrying out further measurements (by pressing "Y").

More Tests: 'Y'/'N' (Yes/No)

If the measurement was incorrect, as in the following example, then a graph appears on the monitor with the words ILLUMINATION NOT CORRECT for approx. 3 seconds:



Thereafter the program returns to the measurement menu (see beginning of chapter) for a new adjustment and repetition of the measurement. The illumination should be readjusted until a homogeneity of the microscope image--within the given tolerances--results.

If the selected photometer signal is too low or too high, the measurement is stopped and the following is indicated on the monitor:

SIGNAL TOO HIGH

or

SIGNAL TOO SMALL

The program returns to the measurement menu for resetting of the photometer's signal and repetition of the measurement.

When the program is in the measurement menu, the following keys can be used to move or turn the measuring slit:

This chart indicates the keys and their corresponding functions:

HP 85 key	Function
←	Measuring slit moves to the left
→	Measuring slit moves to the right
INS/RPL	Measuring slit turns counter-clockwise
-CHAR	Measuring slit turns clockwise

The possibility of turning the measuring slit allows for a check of illumination uniformity in any movement direction of the measuring slit.

To stop the program at any time, press K8 (EXIT).

3. Calibration with a Grating Constant

The program CALGRT serves to calibrate the system with the aid of a standard.
It is suitable for any standard in incident or transmitted light which has a grating constant (PITCH).

The system must always be calibrated when an objective, nosepiece or measuring tube is exchanged. If an objective which should be used for measuring is not calibrated, the program will not execute the measurement.

When the program menu is on the monitor, the calibration program can be called by pressing key "2".

3.1 Determining Measurement Parameters and the Objective to be Calibrated

After the cassette has been inserted, the program appears as shown below:

```
Leitz CD CALIBRATION Program
         CALGRT

for calibrating objectives
with the SHERMAN-standard ?

New standard name or  END LINE ?

LEITZ
Standard constant: 100
New value or END LINE ?
10
```

In this print-out the name of the calibration standard last used is indicated. If required this name can be changed. The total length of the new code word may not exceed 16 characters.

To complete this entry press END LINE.

Furthermore the standard's grating constant must be determined. When the same standard and constant are always used, then pressing END LINE effects their continued use.

We will use the LEITZ standard with a grating constant of 10µm in our calibration.

After completion of this entry, the actual state of the optics used appears on the monitor; the objectives are numbered and their nominal as well as calibrated magnifications are indicated:

```
CALIBRATING IS DONE FOR
OBJ.     NOMIN.MAGN.     CAL.MAGN.

# 1         16x           16.157x
# 2         32x           32.155x
# 3         80x          not calibr.
# 4 not used
# 5        100x          not calibr.
Which objective #?
Obj# 3  80 X
```

If an objective code is not assigned an objective, then the words "not used" appear under the corresponding number. Non-calibrated objectives are marked "not calibr." under their corresponding code number.

Once the objective number is typed in, the system searches for the objective to be calibrated. In our case we select the objective with number "3".
This objective is to be placed into the nosepiece. Focus the standard.

Now the measurement time is to be determined. The system offers the operator the time span last used, in our example a measurement time of 2 seconds:

```
Enter scan time          2
(1...9 sec per structure)
3
```

The operator can choose between 1 and 9 seconds. We will use 3 seconds.

In this case as well the input is completed by pressing END LINE.

3.2 Measurement Preparations

The system is now ready for measuring tasks. The monitor displays the measurement menu with information concerning adjustment of the measuring slit in relation to the object's structure.

```
                    Pos.:  40.32µm
                  *
Please adjust measuring slit on
your standard.
The slit should be immediately
to the LEFT of the test region
The slit length should be
SHORTER than the geometry
The slit must be PARALLEL
to the edge!
------------------------------
                              EXIT
MEASUREMENT          TEST
```

This adjustment of the measuring slit to the object's structure is executed using the following keys:

HP 85 key	Function
↑	Lengthening of measuring slit
↓	Shortening of measuring slit
←	Measuring slit moves to the left
→	Measuring slit moves to the right
INS/RPL	Measuring slit turns counter-clockwise
-CHAR:	Measuring slit turns clockwise

Furthermore the measuring slit's position (in reference to an end of the travel range and to the object) is indicated in the uppermost line. In addition the relative measuring-slit position is marked by the position of an asterisk * in the second line.

Measurements may not be started until the photometer's signal has been checked. During a measurement this signal must remain within the range of reception, and the available intensity resolution (max. 1,024 intensity value increments) should, when possible, be fully utilized.

To check the photometer's signal, move the measuring slit to the brightest spot of the structure to be investigated. Press K3 (TEST) or ROLL. The following print-out will appear on the monitor:

L I G H T C O N T R O L

```
If ready press        END LINE
Auto-adjust press     SPACEBAR
 844
```

In the line above the bar (to the left) is the photometer's measured value. The length of the bar is proportional to this value.

If the measuring system is equipped with an adjustable stabilised power unit for object illumination, then an automatic adjustment of the illumination level can be executed.

After pressing of the SPACE BAR the level of illumination is changed until a photometer value of 800 results. Should the illumination level exceed or fall below the aforesaid limit value, a corresponding warning is displayed on the monitor:

INCREMENT GAIN

or

DECREMENT GAIN

The optimal photometer signal value is also attained by setting the high voltage and/or the photometer amplification.

If an automatic adjustment of the illumination level is not possible, then manual adjustment of it, the high voltage and of the photometer amplification will set the desired photometer signal value.

A warning signal sounds when the photometer's signal exceeds a value of 1,000.

Adjustment of the photometer's signal is completed with END LINE.

3.3 Calibration Measurement

After completion of the measurement preparations, the actual calibration measurement can be started by pressing K1 (MEASUREMENT) or RUN.

Caution!

To avoid causing vibrations during the measurement process, do not touch the microscope. A reminder is displayed on the monitor:

```
PLEASE DONT TOUCH THE MICROSCOPE
 START MEASUREMENT

WAIT FOR A BEEP
```

The end of the measurement procedures is indicated by a beep.
Thereafter the measured intensity profile appears on the monitor for approx. 3 seconds and is then replaced by the display shown below:

```
                    Pos.:  41.68µm
                      *
Threshold from  30 to 35 %  5 x.

Accepted:     'Y'/'N'  (Yes/No)

Restart:                  'R'

From,to,X?
45,55,5
```

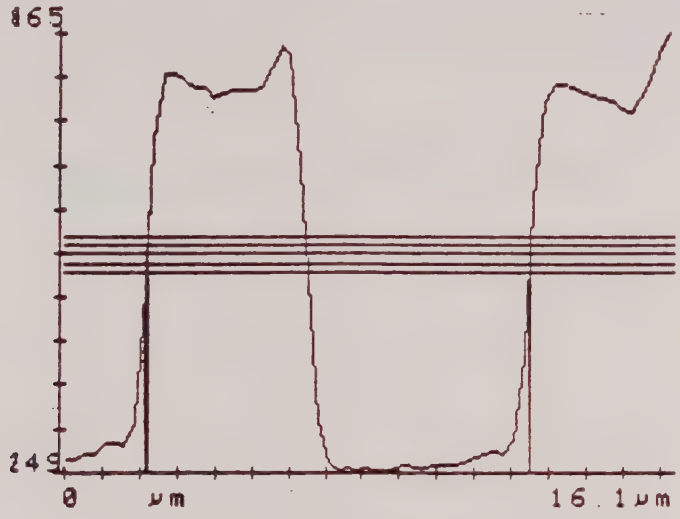
The first two lines indicate the momentary position of the measuring slit, in reference to the object and an end of the travel range. The following lines concern determination of a threshold value. The threshold value is given in percent, whereby the maximum of the intensity profile corresponds to the 100% value and its minimum to the 0% value.

From the last calibration 5 equidistant threshold values between 30% and 35% were determined. To accept these previously entered values, press the key "Y" (Yes), otherwise press "N" (No). In this example we shall use 5 threshold values between 45% and 55%.

Complete the entry with END LINE.

If a measurement must be repeated, this can be effected by pressing "R" (Restart). The program then returns to the measurement menu (see start of section 3.2).

Once the threshold values are determined, the intensity profile, with these values drawn in and with its grating constant, appears for a short time on the monitor:



From this grating constant the objective's magnifications are calculated and displayed on the monitor. In addition the mean value and the standard deviation of these magnifications are determined:

```
MAGN. OBJ#3= 81.548
MAGN. OBJ#3= 81.806
MAGN. OBJ#3= 81.677
MAGN. OBJ#3= 81.419
MAGN. OBJ#3= 81.548

MEAN MAGN. = 81.600
STANDARD DEV.   .147

Are there other
optics to calibrate
then press 'Y'
```

If it is necessary to calibrate other objectives or to repeat the previous calibration, then "Y" (Yes) is to be pressed; the program returns to start so that additional calibration measurements can be carried out.

To interrupt calibration procedures and return to the program menu, END LINE must be pressed or, when in the measurement menu, K8 (EXIT).

3.4 Possibilities of Error

Before starting the measurement process, the program checks the measurement parameters, such as objective magnification, measurement time and measurement distance. When these parameters have been incorrectly entered, the following explanation, coupled with a beep, appears on the monitor:

```
ERROR IN OBJECTIVE# OR STANDARD
WIDTH!
```

or

```
ERROR IN SPEED OR OBJ
```

and the program returns in order to allow re-entry of the measurement parameters.

Another error can occur when measuring near the end of the measurement range.
If the end switch is reached during the measurement process, then the following question appears in connection with a beep on the monitor:

```
END SWITCH REACHED?
```

After repositioning the measuring slit correspondingly, the calibration measurement can be repeated.

4. Calibration with a Reference Structure

The program CALSTR serves to calibrate the system with the aid of a reference structure.

In practice it is often necessary to perform comparative measurements in regards to a reference structure. With this aim in view the width of the reference structure is measured, for example by electron optics, and the light-optics measuring instrument (in our case the MPV-CD) is calibrated to this measured value.

In this program calibration is performed by searching for a threshold value, in which the previously given nominal width value is equal to the actual width value of the reference structure.

The possibility of calibrating with a reference structure using a structure-width correction also exists. This calibration variant is introduced to the operator in program INTAME. With this calibration the nominal structure width is attained by adding a constant value to the measured structure-width value and/or by multiplying this measured value with a constant factor.

With the program menu in view, the program for structure width calibration can be called by typing in the number "3".

4.1 Determining the Measurement Parameters

In this section the necessary measurement parameters are determined. The input is always to be completed with END LINE.

After the program has been loaded and transmitted, the display below appears on the monitor:

```
Leitz CD CALIBRATION Program
        CALSTR

for calibrating the unit with
a reference structure

Ref. structure identification:
STRUCTURE A?
STRUCTURE B
```

The operator has the possibility here of entering a name for the reference standard. The maximum length of the standard's code word may not exceed 16 characters. The name of the reference standard previously used is offered for continued use.

With the next entry the reference structure's nominal width is determined. The nominal structure width last used, that of 10µm, will be offered. We choose a nominal width of 4.5µm:

```
Structure nom. width 10 µm?
4.5
```

With the next input the objective magnification is determined. The operator enters the desired objective code number according to the system's data. We choose the objective 80X:

```
Which objective# ? 1
3
```

Should a non-calibrated objective be under the entered objective code number, then the following is displayed on the monitor:

```
OBJECTIV NOT CAL.!
```

and the program returns to allow redetermination of the objective's magnification.

With the last entry the measurement time is determined. It can lie between 1 and 9 seconds. The operator is offered the preset measurement time or, when available, the time previously used--in this case 2 seconds.

We choose a measurement time of 3 seconds:

```
Please enter scan time
(1...9 sec per structure) 2  ?
 3 sec
```

4.2 Measurement Preparations

Upon completion of these entries, the system is ready for measurement. The monitor displays the measurement menu which contains information concerning adjustment of the measuring slit in reference to the object's structure.

```
                    Pos.:  45.00µm
                           *

Please adjust measuring slit to
 the LEFT of the
 REFERENCE STRUCTURE
The slit should be SHORTER than
 the width
The slit should be PARALLEL to
 the edge.
-------------------------------
                              EXIT
MEASUREMENT          TEST
```

This adjustment of the measuring slit to the object's structure is executed using the following keys:

HP 85 key	Function
↑	Lengthening of measuring slit
↓	Shortening of measuring slit
←	Measuring slit moves to the left
→	Measuring slit moves to the right
INS/RPL	Measuring slit turns counter-clockwise
-CHAR	Measuring slit turns clockwise

Furthermore the measuring slit's position (in reference to an end of the travel range and to the object) is indicated in the uppermost line. In additon the relative measuring-slit position is marked by the position of an asterisk * in the second line.

Measurements may not be started until the photometer's signal has been checked. During a measurement this signal must remain within the range of reception, and the available intensity resolution (max. 1,024 intensity value increments) should, when possible, be fully utilized.

To check the photometer's signal, move the measuring slit to the brightest spot of the structure to be investigated. Press K3 (TEST) or ROLL. The following print-out will appear on the monitor:

L I G H T C O N T R O L

```
If ready press        END LINE
Auto-adjust press     SPACEBAR
 891
*********************************
```

In the line above the bar (to the left) is the photometer's measured value. The length of the bar is proportional to this value.

If the measuring system is equipped with an adjustable stabilised power unit for object illumination, then an automatic adjustment of the illumination level can be executed.

After pressing of the SPACE BAR the level of illumination is changed until a photometer value of 800 results. Should the illumination level exceed or fall below the aforesaid limit value, a corresponding warning is displayed on the monitor:

INCREMENT GAIN

or

DECREMENT GAIN

The optimal photometer signal value is also attained by setting the high voltage and/or the photometer amplification.

If an automatic adjustment of the illumination level is not possible, then manual adjustment of it, the high voltage and of the photometer amplification will set the desired photometer signal value.

A warning signal sounds when the photometer's signal exceeds a value of 1,000.

Adjustment of the photometer's signal is completed with END LINE.

4.3 Calibration Measurement

After completion of the measurement preparations, the actual calibration measurement can be started by pressing K1 (MEASUREMENT) or RUN.

Caution!

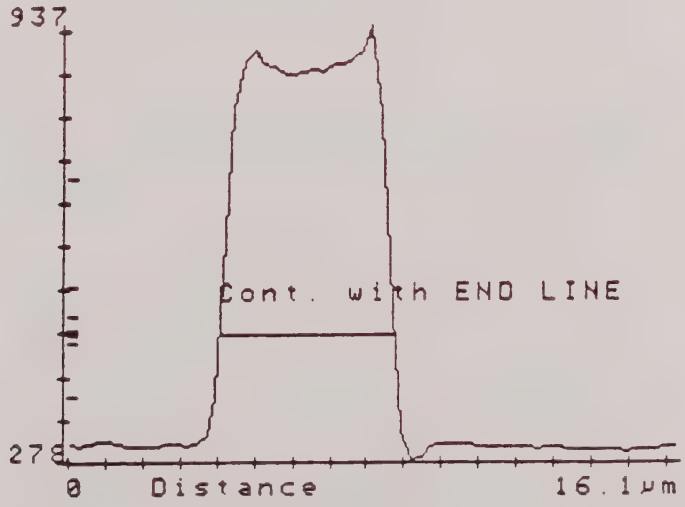
To avoid causing vibrations during the measurement process, do not touch the microscope. A reminder is displayed on the monitor:

```
PLEASE DONT TOUCH THE MICROSCOPE
 START MEASUREMENT

WAIT FOR A BEEP
```

The end of the measurement procedures is indicated by a beep.

If no errors were made during input of the measurement parameters and positioning of the slit (see next section), and if, moreover, the measured structure width, in the 15% to 65% range of the intensity profile, is the same as the nominal structure width, then the following graph will appear on the monitor:



Should the measured structure width in the above-mentioned range not be equal to the nominal structure width, the intensity profile will be displayed for a short time on the monitor, to be then replaced with the following comment:

INPUT ERROR

A warning signal sounds concurrent with this error display, and the program returns to start for re-entry of the measurement parameters.

To ascertain the found threshold, END LINE must be pressed. The value in question will then appear on the monitor:

```
Threshold = 29.4 %

Accepted:   'Y'/'N'   (Yes/No)
```

If satisfied with this value, the operator must press "Y" (Yes), otherwise the key "N" (No).

With "Yes" the program is stopped; with "No" the operator can manually enter a threshold value or repeat the calibration:

```
SET  → Threshold          'S'
NEW  → New Measurement    'N'
```

To manually enter a threshold value, the "S" (Set) key must be pressed. The following text is then displayed on the monitor:

```
Enter threshold:
?
20
Threshold = 20  %

Accepted:   'Y'/'N'   (Yes/No)
```

In our example a threshold of 20% was chosen.

Input of this percentage is completed with END LINE.

In order to perform additional calibration measurements, "N" (New measurement) must be pressed instead of "S". The program then returns to start for re-establishment of the measuring parameters.

The stopping of calibration measurements and subsequent return to the program menu can also be effected by pressing K8 (EXIT) in the measurement menu.

The last indicated or manually-determined threshold value is taken over by the system and offered to the operator in program "5" (INTAME).

4.4 Possibilities of Error

Before starting the measurement process, the program checks the measurement parameters, such as objective magnification, measurement time and measurement distance. When these parameters have been incorrectly entered, the following explanation, coupled with a beep, appears on the monitor:

OBJECTIV NOT CAL.!

when the objective is not calibrated,

ERROR IN OBJECTIVE# OR STANDARD WIDTH!

when the combination of objective and nominal structure width was incorrectly selected or

SPEED ERROR

when the combination of nominal structure width and measurement time was incorrectly selected.

After displaying one of these error messages, the program returns to start for re-input of the measurement parameters.

Another error can occur when measuring near the end of the measurement range.
If the end switch is reached during the measurement process, then the following question appears, coupled with a beep, on the monitor:

END SWITCH?

After repositioning the measuring slit correspondingly, the calibration measurement can be repeated.

5. Simple, automatic Structure Width Measurement on Masks

The program OPSMEA was especially developed for the measurement of structure widths on masks in semiconductor production.

With this program the operator is capable of performing fast and reliable measurements of any structure's width.

To be able to carry out a series of measurements, the operator must simply select the objective and determine the approximate structure width as well as its correction. This does not require prior input of the measurement parameters.

All measurement and analysis parameters, which were not mentioned above, have been determined as follows:

Smoothing factor (Smoothing of intensity profile):	4
Measurement time	: 3 seconds
100% value	:Maximum of intensity profile
Measurement pos.	:Flanks of one structure only
Threshold value	: 50%

Once the required parameters have been determined, the width of any structure can be measured on as many different objects (masks) as desired. It is possible to statistically evaluate these measurement results and to store them on the system cassette.

Since reliable and speedy work is important in production, the system was equipped with a compact keyboard with which in this program only the execution of slit operations (orientation of slit to object's structure), the checking of the photometer and the starting and ending of measurements is still possible.

When the program menu is on display, the OPSMEA program is called by pressing "4".

After the program has been loaded and transmitted, its identification appears on the monitor:

Leitz AUTOMATIC Program
OPSMEA

for simple structure
measurements on masks

The program then branches for input of the required measurement parameters.

5.1 Determining the Measurement Parameters

First of all the objective is chosen. A list of the available objectives with their nominal magnifications, calibration states and code numbers is shown on the monitor:

```
THE FOLLOWING OPTICS ARE
CALIBRATED:
# 1 :   16x     16.17
# 2 :   32x     32.16
# 3 :   80x     81.60
# 4 uncalibrated or unused
# 5 :  160x    158.00

Please enter objective # 1   ?
Objective # 3     80  x
```

The operator is offered the objective number which was previously entered. By pressing END LINE the operator can continue to use this number. If a different magnification than that being offered is desired, however, then the corresponding objective number must be typed in.

If a calibrated objective is not available under the entered number, the system indicates the following:

```
not calibrated
```

If no objective was assigned to the chosen code number, then the comment below appears:

```
not used
```

With the input of a more suitable objective code number, the selection of an objective is ended.

In this example we have chosen objective 80X.

Now the approximate structure width will be determined. The command to enter an approximate structure width in "um" appears on the monitor with the preset value of 5um or with the approximate structure-width value used in the previous measurement.

The operator can press END LINE to effect the take-over of this value, or he can enter a new value before pressing END LINE.

```
Enter approx. structure
width (µm)  5 µm ?
10
```

In our example we have chosen an approximate structure width of 10µm.

The determination of an approximate structure width can also occur as follows:

1. Choose objective to be used.
2. Take over value last given for approx. structure width and its correction.
3. Move measuring slit to end points of structure to be measured and register corresponding values at these positions (uppermost line of measurement menu; see next section). The difference of these position values yields the approx. structure width.
4. Return to program start via EXIT to enter the approx. structure width.

With this last entry the structure width's correction is determined. Determination of the correction is required because the threshold in this program has a fixed value. The structure-width correction can either be additive (adding of a constant value to measured value) or multiplicative (multiplying measured value with a constant factor).

After the input for the approximate structure width has been executed, the following display appears on the monitor:

```
Additive correction: -.25 µm
Multipl. correction: 1 x

Change:    'Y'/'N'   (Yes/No)
```

The operator is offered the structure-width corrections last used in the current objective magnification. If he accepts these values, he must press "N" (No) or END LINE, otherwise "Y" (Yes) on the HP 85.

When the correction factors have not been accepted (key "Y"), the following text appears on the monitor:

```
Enter offset?
0
Enter factor?
1
```

The operator can now enter the desired correction values.

We have chosen an additive correction of 0um and a correction factor of 1.

Each input is completed with END LINE .

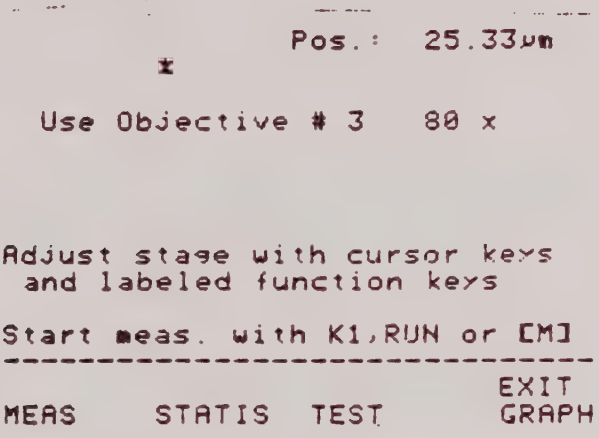
Important!

1. The additive correction for structure width is entered in "µm".
2. The indicated structure width is ascertained from the correction values and the measured structure width using the following formula:

Indicated structure width = (multiplicative factor) X (measured value) + (additive constant)

5.2 Measurement Preparations

After the measurement parameters have been determined, the system is ready for measurement. The monitor displays the measurement menu with information concerning adjustment of the measuring slit in reference to the object's structure.



This adjustment of the measuring slit to the object's structure is executed using the following keys:

Compact Keyboard key	HP 85 key	Function
↑	↑	Lengthening of measuring slit
↓	↓	Shortening of measuring slit
←	←	Measuring slit moves to the left
→	→	Measuring slit moves to the right
↖	INSRPL	Measuring slit turns counter-clockwise
↗	-CHAR	Measuring slit turns clockwise

Furthermore the measuring slit's position (in reference to an end of the travel range and to the object) is indicated in the uppermost line. In addition the relative measuring-slit position is marked by the position of an asterisk * in the second line.

As already mentioned in the previous section, the display of the measuring slit's momentary position can be used in order to determine the approximate structure width.

Measurements may not be started until the photometer's signal has been checked. During a measurement this signal must remain within the range of reception, and the available intensity resolution (max. 1,024 intensity value increments) should, when possible, be fully utilized.

To check the photometer's signal, move the measuring slit to the brightest spot of the structure to be investigated. Press ROLL, K3 (TEST) on HP 85 or "P" on the compact keyboard. The following print-out appears on the monitor:

L I G H T C O N T R O L

```
IF ready press  K3, ROLL or [P]
Auto-adj. press SPACEBAR or [#]
 790
**************************
```

In the line above the bar (to the left) is the photometer's measured value. The length of the bar is proportional to this value.

If the measuring system is equipped with an adjustable stabilised power unit for object illumination, then an automatic adjustment of the illumination level can be executed.
After pressing of the SPACE BAR on HP 85 or the key "#" on the compact keyboard, the level of illumination is changed until a photometer value of 800 results. Should the illumination level exceed or fall below the aforesaid limit value, the following appears on the monitor:

INCREMENT GAIN

or

DECREMENT GAIN

The optimal photometer signal value is also attained by setting the high voltage and/or the photometer amplification.

If an automatic adjustment of the illumination level is not possible, then manual adjustment of it, the high voltage and of the photometer amplification will set the desired photometer signal value.

A warning signal sounds when the photometer's signal exceeds a value of 1,000.

Adjustment of the photometer's signal is completed by repeatedly pressing K3 (TEST), ROLL on HP 85 or "P" on the compact keyboard.

5.3 Executing Measurement

After the preparations have been completed, measurement can be started. This is done either by pressing K1 (MEAS), RUN on HP 85 or key "M" on the compact keyboard.

Caution!

To avoid causing vibrations during the measurement process, do not touch the microscope. A reminder is displayed on the monitor:

```
DONT TOUCH THE MICROSCOPE
=========================
```

The end of the measurement procedures is indicated by a beep.

If the measurement was performed correctly, the following display appears on the monitor:

```
Objectiv : 80 x

Width =    9.25 µm

N:  2  σ: 0.00µm Mean:  9.24µm
with Threshold  = 50 %


Accept result with SPACE or [#]
Reject result with RUN,K1 or [M]

hold key for print
------------------------------
                           EXIT
REJECT  STATIS            GRAPH
```

This display contains the measured and possibly also the corrected structure-width value.
The correction of this measured value was carried out according to the structure-width corrections that were entered (see section 5.1).

In addition to the measured value, the number of the measurement in the current measurement series, the statistical values (mean value and standard deviation) and several of the measurement parameters used are indicated.

Important!

1. The measured value displayed is rounded off to 2 digits after the decimal point.

2. The statistical values (mean value and standard deviation) refer to the measured value before it is rounded off.

3. The accuracy of the measurement is determined by the numerical resolution of the measurement distance. The formula below results:

$$\Delta = W / 1000$$

with

W : Travel distance of measuring slit (in ref. to object) during measurement process

If the existing measurement result is accepted, the SPACE BAR on HP 85 or key "#" on the compact keyboard must be pressed. This reading is thereby recorded in the statistics.

The period of time in which the SPACE BAR or "#" key is depressed determines whether this measurement result will be printed or not. When the depression time is short, a print-out is suppressed, and the program branches to the measurement menu for further measuring tasks. In the other case the reading together with its corresponding measurement number is printed, before return of the program to the measurement menu.

N: 1 Result: 9.23µm

In addition K2 (STATIS) enables the operator to print the displayed statistical values (mean value and standard deviation) as well.
With print-out of statistical values it is to be noted that the last measured value will be automatically recorded in the statistics.

Of course one still has the possibility of repeating measurement, should the result have been erroneous. To do so, one must press the release key (K1, RUN, "M") again, in place of the accepting key (SPACE BAR, "#"). Measurement will begin, and the incorrect result will neither be printed nor recorded in the statistics.

Incorrect measurement can be the result of vibrations, electrical disturbances or a set of measurement parameters which does not correspond to the structure being measured. In order to localize the source of error, it is absolutely necessary to graphically represent the

L I G H T C O N T R O L

```
If ready press        END LINE
Auto-adjust press     SPACEBAR
 878
```

In the line above the bar (to the left) is the photometer's measured value. The length of the bar is proportional to this value.

If the measuring system is equipped with an adjustable stabilised power unit, an automatic adjustment of the illumination level is thus possible.
After pressing of the SPACE BAR the level of illumination is changed until a photometer signal value of approx. 800 results. Should the illumination level exceed or fall below the aforesaid limit value, a corresponding warning is displayed on the monitor:

INCREMENT GAIN

or

DECREMENT GAIN

The optimal photometer signal value is also attained by setting the high voltage and/or the photometer amplification.

If an automatic adjustment of the illumination level is not available, then manual adjustment of it, of the high voltage and of the photometer amplification will achieve the desired photometer signal value.

A warning signal sounds when the photometer signal exceeds a value of 1,000.

Adjustment of the photometer's signal is completed with END LINE.

6.4 Interactive Structure Width Measurement

In the interactive part of this program the analysis parameters, required for structure width determination, are ascertained from the intensity profile. These parameters, as also the entered measurement parameters, can be stored as a measurement parameter set for future use in the OPER program.

6.4.1 Simple Structure Width Measurement

As already mentioned in section 6.2, it is possible to very quickly and easily determine the approximate structure width.

To determine the width drive the measuring slit to the edges of the structure to be measured and note each of the position values indicated (see measurement menu in section 6.3). The difference of these position values is the structure-width value.

Important!

The measured value determined in this manner is subject to error due to false positioning of the slit. The determination of structure width using the intensity profile, however, is performed with a much higher degree of accuracy.

6.4.2 Execution of Measurement with Selection of Threshold and 100% Values

To enable determination of structure width, a measured intensity value must be defined from the established intensity profile. This intensity value is obtained by selecting the proper threshold value (in percent) and a 100% value (maximum of intensity profile or background intensity). The 0% value is defined by the minimum of the intensity profile.

Upon completion of the preparations, measurement can be started. The measurement is begun with either the key K1 (MEAS) or the key RUN on HP 85.

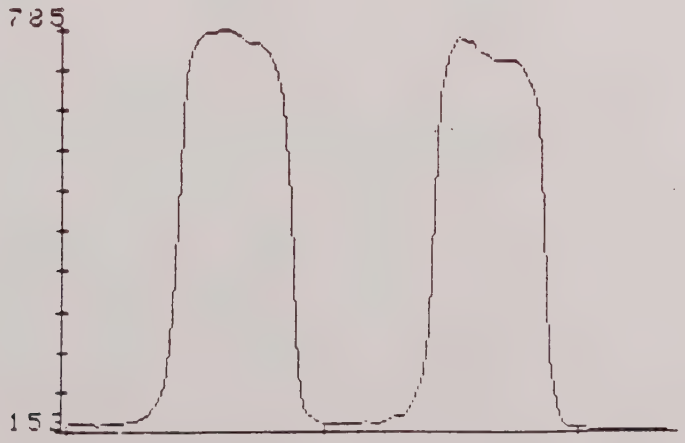
Caution!

To avoid causing vibrations during the measurement process, do not touch the microscope. A reminder is displayed on the monitor:

```
DONT TOUCH THE MICROSCOPE
=========================
  learn mode
```

The end of the measurement procedures is indicated by a beep.

If the measurement was performed correctly, the measured intensity profile will appear as a graph on the monitor:



The largest and smallest intensity values measured are on the graph at the top and bottom left side respectively.

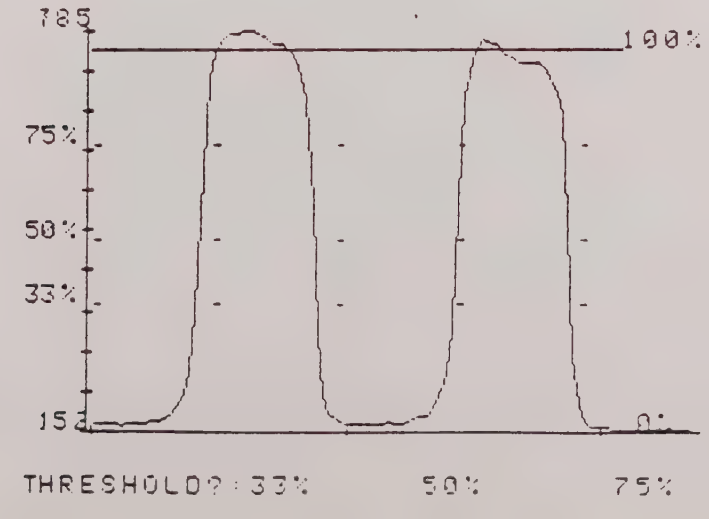
The 100% value is determined with key K2 (BACKGR) or K3 (MAXIMUM). Each key is explained below:

K2 : The mean value of the first 50 intensity values is defined as 100%. This determination is of interest with, for example, wafers, since the background of the structure to be measured shows a noticeably high reflection value.

K3 : The maximum intensity value reduced by 5% is defined as 100%. This determination has proven to be advantageous, for example with masks, since the maximums of these objects' intensity profiles are caused primarily by diffraction effects. The by 5% reduced maximum intensity value corresponds approximately to the mean reflection factor of the structure to be measured.

If the measurement was not satisfactorily performed, it can be repeated at any time by pressing K4 (REMEAS). The program branches first to the program stop menu (see section 6.6), wherein the operator decides if measurement should be executed with the same or with new measurement parameters.

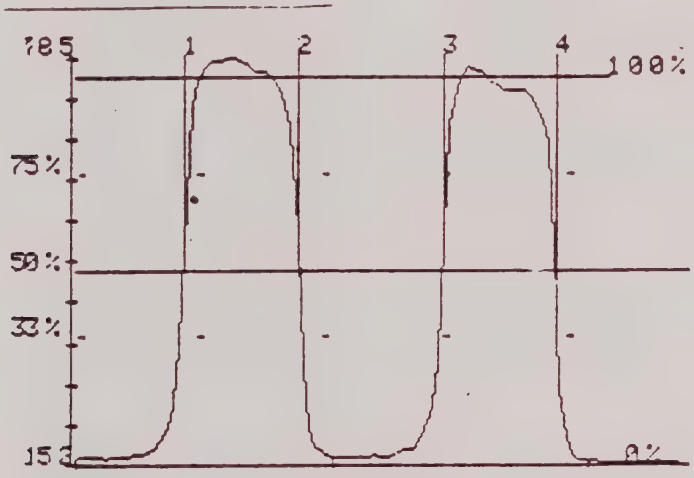
After definition of the 100% value, in our case of the maximum as 100%, this value is entered in the graph. In addition the three threshold values determined in section 6.2, in reference to this 100% value, are drawn in with marks and indicated numerically.



The operator now has the possibility of choosing a suitable threshold value from the three being offered via keys K2-K4.

In our example we select (via K3) the second threshold value of 50%. This threshold value is now entered in the graph.

Furthermore the intersection points of the intensity profile along with the chosen threshold value are indicated by a maximum of 9 vertical marks. During structure width determination in this program only these first 9 intersection points are taken into consideration. The individual intersection points are numbered consecutively from left to right:



Upon completion of the graph the learn table shown below appears on the monitor before the first structure width determination.

```
LEARN TABLE
S  Repeat with same parameters
N  Repeat with  new parameters
G  Calculation by Graph
T  Different threshold
R  Reset threshold values
P  Print all distances
D  Disp  all distances
E  EXIT to MENU

also active: GRAPH/ COPY/ PAPER
enter select code:
```

This learn table is supplemented with the following options after the first structure width calculation:

L Print last Result
A Automatic measurement
O STORE Operator parameters

With the aid of this learn table the operator has the possibility of changing the measurement and analysis parameters, executing measurement with the same and with new measurement and analysis parameters, performing structure width calculations in various ways, storing measurement data and measurement parameter sets as well as carrying out measurement series with their corresponding statistical analyses.

An explanation of each option in the table is given in the next and in the following sub-sections.

To execute the desired operation, the key indicated must be pressed.

The last graphic representation of the intensity profile appears on the monitor via the GRAPH key or is printed via the COPY key. The paper can be advanced by pressing PAPER ADVANCE.

A change of the analysis parameters can be performed via keys "T", "R" and "S", of the measurement and analysis parameters via "N". The individual possibilities, which result after one of the above keys has been pressed, are discussed below:

T : After depression of the key "T", the program branches for re-determination of the three selectable thresholds and of the 100% value. From the newly defined threshold values, that desired is chosen and together with the 100% value is entered in the intensity profile.

R : With "R" the operator is given the possibility of selecting another threshold value from the three being offered as well as of redefining the 100% value. Also in this case the newly selected threshold and 100% values are entered in the intensity profile of the present measurement.

N : With "N" a new measurement is started with the possibility of modifying the measurement and the previous analysis parameters.

S : With key "S" the program returns to the measurement menu (see section 6.3) for the execution of additional measurements. Measurement parameters remain the same, the previous analysis parameters are re-determined, taking the new intensity profile as a basis.

Together with the measured value the objective magnification, the corresponding threshold value and the measurement positions of the intensity profile are shown. The measurement positions can be either the intersection points of the intensity profile with the threshold (EDGE), the mean values of these intersection points (MID) or also the minimums or maximums between these intersection points (MIN, MAX).

In addition the number of the measurement within this measurement series and the statistical values (mean value and standard deviation) of the accumulated measured values are displayed on the monitor:

Important!

1. The given measured values are rounded off to two digits after the decimal point.

2. The statistical values, such as mean value and standard deviation, refer to the measured values before they are rounded off.

3. The accuracy of the measurement is determined by the numerical resolution of the measurement distance. The formula below results:

$$\Delta = W / 1000$$

with

W : Travel distance of the measuring slit (in reference to the object) during the measurement process.

If the existing measurement result is accepted, the SPACE BAR on HP 85 or key "#" on the compact keyboard must be pressed. This reading is thereby recorded in the statistics.

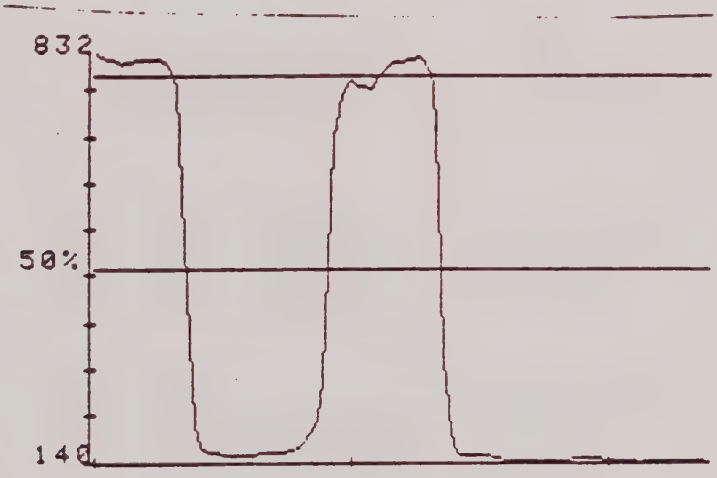
The period of time in which the SPACE BAR or "#" key is depressed determines whether this measurement result will be printed or not. When the depression time is short, a print-out is suppressed, and the program branches to the measurement menu for further measuring tasks. In the other case the reading together with its corresponding number is printed, before return of the program to the measurement menu.

N: 2 Result: 10.02µm

It is possible to repeat measurement should the result have been erroneous. To do so one must press the key K1(REJECT) or RUN on HP 85 or the key "M" on the compact keyboard instead of the acceptance key (SPACE BAR, "#"). Measurement begins, and the incorrect result is neither printed nor recorded in the statistics.

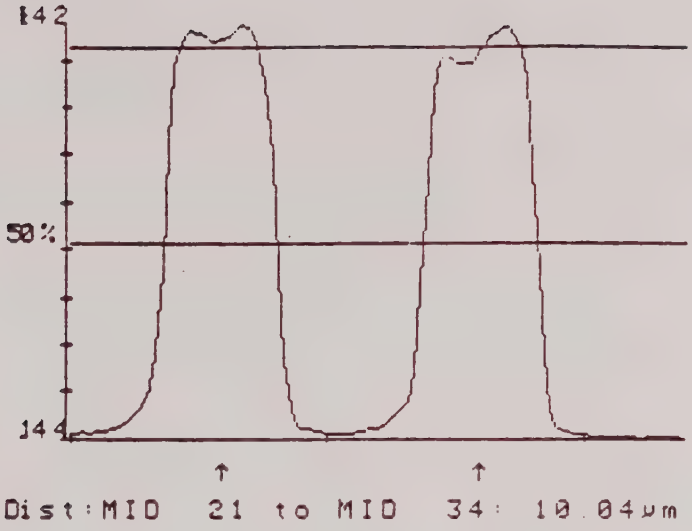
Incorrect measurement can be the result of vibrations, faulty positioning of the measuring slit, electrical disturbances or a set of measurement parameters which does not correspond to the structure being measured.

In order to localize the source of error, it is absolutely necessary to graphically represent the measured intensity profile together with the analysis parameters. This can be effected by pressing the key K4(GRAPH).



Using this intensity profile the operator can now easily locate the source of error.

In addition to the analysis parameters (100% value, threshold value and measurement-position definition), the ascertained measured value is also included in this graph:



This graph can be printed via COPY.

To return to the measurement menu, the operator must press key K1 or RUN on the HP 85 or "M" on the compact keyboard.

The statistical analysis (mean value and standard deviation) of the available measured values can be printed after the completion of each measurement. A print-out results from depression of key K2 (STATIS) in the measurement menu.

In the following example a statistical evaluation of the measured values was carried out after the 5th and 10th values in this measurement series:

```
Results for file STRUC A
 with code A

N:  1   Result: 10.04µm
N:  2   Result: 10.02µm
N:  3   Result: 10.04µm
N:  4   Result: 10.04µm
N:  5   Result: 10.02µm
N:  5  σ: 0.01 Mean: 10.03µm
N:  6   Result: 10.04µm
N:  7   Result: 10.07µm
N:  8   Result: 10.02µm
N:  9   Result: 10.04µm
N: 10   Result: 10.04µm
N: 10  σ: 0.02 Mean: 10.04µm
```

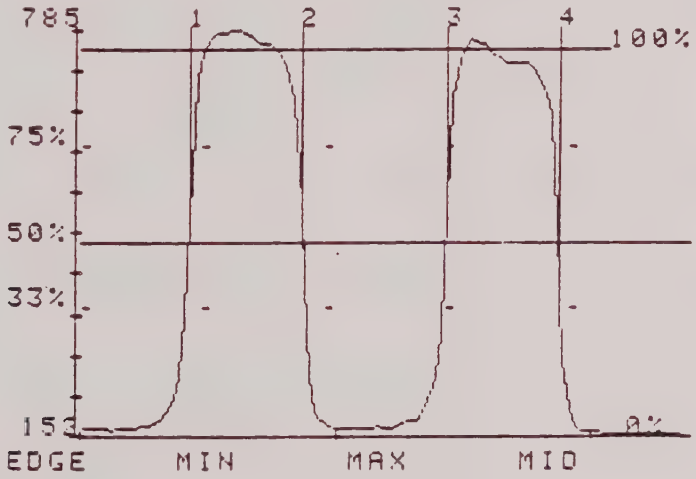
If a new series of measurements must be performed using the same parameters (numbering of the measurements begins with the number "1"), then "E"+"Y" on HP 85 or the compact keyboard is to be pressed in the order given. The program lists the codes of the available measurement parameter sets on the monitor, and the operator types in the code letter of the desired parameter set (see next

6.4.3 Defining the Measurement Positions and Determining Structure Width

In addition to the threshold and 100% values, definition of the measurement positions is required in order to determine the structure width.

The measurement positions can be either the intersection points of the intensity profile with the threshold, the mean values of these intersection points or also the minimums or maximums between these intersection points (see also graph below).

In order to determine the measurement positions (the last analysis parameters), and thereby the yet undefined structure width, key "G" must be pressed. The intensity profile with the 100% value, the threshold value and the intersection-point lines will appear on the monitor:



Below the graph the functions of keys K1-K4 are displayed. With the aid of these keys the operator can determine his measurement positions and thereby the structure width as well.

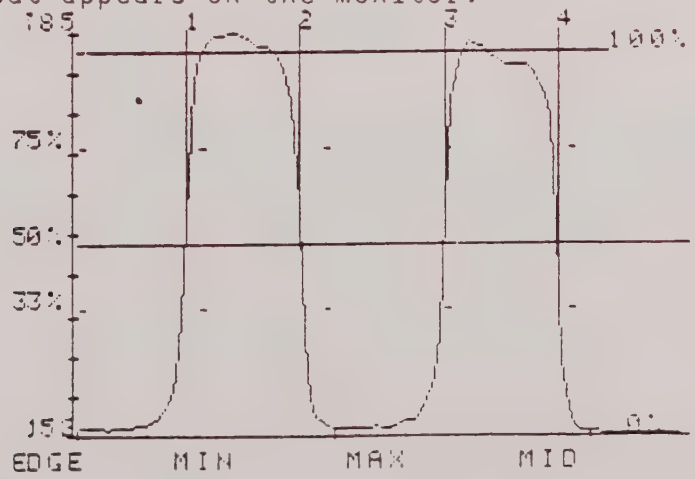
An explanation of the individual keys follows:

- K1 : Type of measurement chosen is with an intersection point (EDGE). After selection of this kind of measurement, the number of the chosen intersection point must be entered.
- K2 : Type of measurement chosen is with a minimum (MIN). The minimum is between two intersection points that are to be entered.
- K3 : Type of measurement chosen is with a maximum (MAX). The maximum is between two intersection points that are to be entered.
- K4 : Type of measurement chosen is with the mean value from any two intersection points that are to be entered.

Structure width is concretely determined in the following manner:

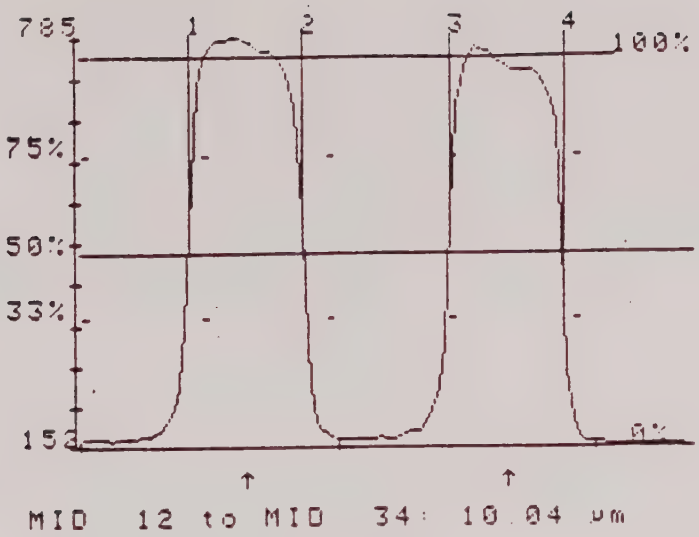
1. Selection of the type of measurement to be used for the first measurement position by depression of key K1-K4.
2. Input of the desired intersection point (1-9) or of the desired intersection-point combination (11-99) and completion of entry for this measurement position with END LINE. A correction of the intersection-point choice is possible before completion of the entry via BACK SPACE key.
3. Selection of the type of measurement to be used for the second measurement position by depression of key K1-K4.
4. Input of the desired intersection point or intersection-point combination corresponding to point 2. The structure-width value appears in um in the last line on the monitor. Furthermore two arrows marking the measurement positions are displayed in the lower part of the graph.
5. Completion of structure width determination by depression of END LINE.
   The learn table appears on the monitor, and the system is ready for a new structure width determination.

In the following example the center-to-center distance of two Cr lines on a mask was determined according to the above scheme.
For the first measurement position "MID", "2", "1" and END LINE are entered in the order given, for the second position "MID", "3", "4" and END LINE. The following print-out appears on the monitor:



FROM MID :31 TO MID :34

When END LINE is pressed again, the graph is displayed with the structure-width value.



A subsequent pressing of the END LINE key results in the system branching back to the learn table.

The measurement result can be printed out by depression of key "L".

MID 12 to MID 34: 10.04 µm

If along with this result a graphic representation of the intensity profile is desired, then COPY must be pressed.

Display of the intensity profile's graph from the last measurement is possible at all times in the learn table via the key GRAPH.

It is also possible to determine the distances of all successive intersection points for the purpose of a better overview of the executed measurement.
The operator can display these distances on the monitor with "D" or print them out with "P".

Shown below is the print-out of all successive distances of the above sample measurement.

Distances with 50 %:

Edge: 1 to 2 = 4.46µm
Edge: 2 to 3 = 5.61µm
Edge: 3 to 4 = 4.39µm

Important!

1. The displayed measured and possibly corrected value is rounded off to 2 digits after the decimal point.

2. The accuracy of the measurement is determined by the numerical resolution of the measurement distance. The formula below results:

$$\Delta = W / 1000$$

with

W : Travel distance of the measuring slit (in reference to the object) during the measurement process.

6.4.4 The Formation of Measurement Parameter Sets

Once the individual analysis parameters in this interactive part of the program have been determined (with the intensity profile from a structure width measurement), these parameters, as well as the measurement parameters, can be stored as a measurement parameter set.

This measurement parameter set can then be recalled in the automatic program OPER for the execution of measurement series on the type of structure learned.

The measurement and analysis parameters of the measurement last carried out in the interactive part of the program will be stored. In detail the following parameters are stored in the measurement parameter set:

1. Measurement distance
2. Measurement time
3. Objective
4. Smoothing factor of intensity profile
5. Structure-width value of last measurement in interactive part of program
6. Threshold value
7. Maximum of intensity profile or background intensity value as 100% value

8+9. Left and right measurement positions (intersection point, minimum, maximum or mean value)

10. Additive structure-width correction constant
11. Multiplicative structure-width correction factor

The operator has the possibility of storing 22 different measurement parameter sets.

To store the learned measurement and analysis parameters, one presses the key "0" in the learn table or in the menu of the program's automatic part. The codes for all 22 measurement parameter sets will then appear on the monitor:

```
Measurement Files:
A: STRUC 1        B: STRUC 2
C: STRUC 3        D: STRUC 4
E: STRUC 5        F: STRUC 6
G: STRUC 7        H: STRUC 8
I: STRUC 9        J: STRUC 10
K: STRUC 11       L: STRUC 12
M: STRUC 13       N: STRUC 14
O: STRUC 15       P: STRUC 16
Q: STRUC 17       R: STRUC 18
S: STRUC 19       T: STRUC 20
U: STRUC 21       V: STRUC 22

To store parameters press A-V
Space → Change Name  X→Exit
```

The operator now has the possibility of storing the resulting measurement parameter set in one of the 22 files for measurement parameter sets on the system cassette. To obtain the desired file its corresponding code letter (A-V) is to be typed in.

Before the existing measurement parameter set is stored in the selected memory location, the following information appears on the monitor:

```
Selected name code is A
Are you sure ? 'Y'/'N' (Yes/No)
```

The question is to assure that the previous measurement parameter set is not written over by unintentional depression of one of the keys (A-V).

Since as a rule each measurement parameter set must have its own code, the possibility of changing the code of the individual measurement parameter sets exists.
After SPACE BAR has been pressed, the request to enter the letter code of the measurement parameter set to be changed appears on the monitor:

```
Change Code ?
```

After the measurement file has been selected, the desired code of the measurement parameter set must be entered:

```
 STRUC 1     to ?
STRUC A
```

The system takes over this new code, and the modified catalogue of measurement parameter sets is displayed on the monitor:

```
Measurement Files:
A: STRUC A          B: STRUC 2
C: STRUC 3          D: STRUC 4
E: STRUC 5          F: STRUC 6
G: STRUC 7          H: STRUC 8
I: STRUC 9          J: STRUC 10
K: STRUC 11         L: STRUC 12
M: STRUC 13         N: STRUC 14
O: STRUC 15         P: STRUC 16
Q: STRUC 17         R: STRUC 18
S: STRUC 19         T: STRUC 20
U: STRUC 21         V: STRUC 22

To store parameters press A-V
Space  → Change Name  X→Exit
```

The system is prepared to change anew the measurement-parameter-set codes as well as to store additional measurement parameters.

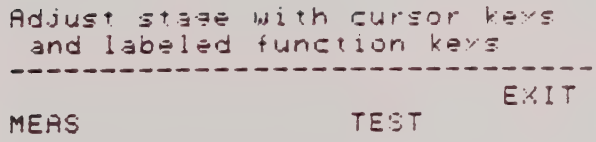
Via key "X" the program branches to its stop routine (see section 6.6).

6.5 Automatic Structure Width Measurement with Data Storage

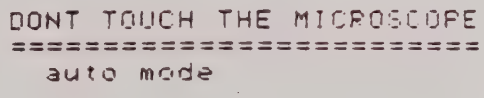
With the aid of this part of the program, it is possible to carry out measurement series in the same way as in the automatic program OPER.

Prior to the creation of a measurement parameter set, the operator can check the obtained measurement and analysis parameters for their usability in a measurement series. It is quite possible that satisfactory results are attained with these parameters during the learn measurement, but that during execution of a measurement series errors occur.

By pressing "A" in the learn table or program stop menu (see next section), the operator obtains the automatic part of the program; the program branches to the measurement menu for automatic measurement:



This measurement menu is identical to that in the interactive part of the program. After measurement is started, however, the mode of operation is displayed on the monitor for the operator:



If the measurement was correctly executed, the measured and corrected (structure-width correction considered) structure width appears on the monitor. In addition the selected threshold value and defined measurement positions are concurrently displayed:

```
MID  12 to MID  34: 10 02 µm
with Threshold 2 = 50 %

N:  2  σ: 0.02µm Mean: 10.01µm
```

Furthermore from the second measured value of the existing measurement series onwards, the number of the measurement, the mean value and the standard deviation of the previous measurement results of this series are displayed.

After this information the table of the automatic measurement mode appears on the monitor:

```
P = Print Result
S = Print Statistics
R = Repeat   Measurement
C = Continue Measurement
N = New Measurement Cycle
O = Operator Program Creation
D = Data Storage
E = Exit
```

The following options are available to the operator by depression of the corresponding keys:

- P : Print-out of present measurement results. These results are corrected (structure-width correction) and rounded off to two digits after the decimal point.
- S : Print-out of number of measurements and of statistical values, such as mean value and standard deviation. Statistical values refer to not yet rounded-off measurement results of existing measurement series.
- R : Repeat of last measurement. Statistical results are corrected accordingly.
- C : Continuation of measurement within present measurement series.
- N : Start of a new measurement series. Statistical values refer from now on to measurement results of this new measurement series.
- O : Creation of a measurement parameter set (see sub-section 6.4.4).
- D : Storage of first 100 corrected measured values with their corresponding statistical values (mean value and standard deviation) and the structure-width corrective amounts (for details see further below).
- E : Stop of program execution with possibility of continuing measurement in automatic and interactive parts of program (details in section 6.6).

The corrected measurement results can be printed after each measurement via "P".

In addition it is possible after each measurement to print out the statistical analysis of the existing measurement results.

In the following example a measurement series to determine the center-to-center distance of two Cr lines on a mask was performed. The statistical analysis was printed after half of the measurement series and at its end:

```
N:  1   Result:  10.00µm
N:  2   Result:  10.02µm
N:  3   Result:  10.02µm
N:  4   Result:  10.02µm
N:  5   Result:  10.02µm
N:  5  σ: 0.01µm Mean: 10.01µm
N:  6   Result:  10.04µm
N:  7   Result:  10.02µm
N:  8   Result:  10.02µm
N:  9   Result:  10.04µm
N: 10   Result:  10.02µm
N: 10  σ: 0.01µm Mean: 10.02µm
```

In the automatic part of the program, measurement data can be stored after each successfully completed measurement.

After depression of key "D" the following display appears on the monitor:

```
STORE DATA 1-100 TO FILE #?
  1..5
```

The operator now has the possibility, by entering the number 1 to 5, of storing the measurement results of the existing measurement series in the file DATA1 to DATA5 on the system cassette.

After storage of the measurement data, the system displays the following message on the monitor:

```
Stored to file DATA1
```

Important!

1. Only the first 100 measurement results of the measurement series at hand can be stored in one of the data files. The former values in these files are written over.
2. If 100 or more measured values of the existing measurement series are available, the following warning appears on the monitor:

   Buffer full! STORE with Key 0

3. It is to be noted that the stored structure-width values are corrected measured values (structure-width correction was already performed).

The following data of the present measurement series is stored in the order indicated:

No.	Variable or Field	Type of Variable or Field	Explanation
1	E1	REAL variable	Sum of measurement results
2	E2	REAL variable	Sum of square of meas. results
3	E3	REAL variable	Number of measured values
4	E4	REAL variable	Mean value of meas. results
5	E5	REAL variable	Standard deviation of these measurement results
6-105	E(100)	INTEGER field	Measurement results Following no. is stored: meas. result X 100 Maximum no. : E3
106	K1	REAL variable	Structure-width correction constant
107	K2	REAL variable	Structure-width correction factor

The values E1 to E5 refer to the corrected measurement results of all measurements in the present series.

For further processing the stored measurement results can be obtained from the memory of the HP 85 with the aid of the following BASIC commands:

```
ASSIGN#1 TO "DATAX"
READ#1 ; E1,E2,E3,E4,E5,E(    ),K1,K2
ASSIGN#1 TO *
```

X = 1,...,5

At the start of the program the data declaration shown below must be at hand:

```
OPTION BASE 1
```

6.6 Stopping the Program

Measurement can be stopped at four different points in this program: in either the measurement menu of the interactive or of the automatic mode, in the learn table, in the table of automatic measurement mode and during the creation of measurement parameter sets.

As long as the first structure width calculation after the calling of this program has not been performed, no complete measurement parameter set is available (determination of measurement positions during structure width calculation). The completeness of the measurement parameter set at the storage of measurement parameter sets and during the execution of measurements in the automatic part of this program is, however, absolutely necessary.

If, prior to the first structure width calculation, K8 (EXIT) in the measurement menu of the interactive measurement mode, K4 (REMEAS) during definition of the 100% value or key "E" in the learn table is pressed, the following stop menu will appear on the monitor:

Return to menu:	'M'
Continue meas.:	'C'
Learn mode:	'L'

This table is supplemented after the first structure width calculation by the option shown below:

Automatic meas.:	'A'

By pressing the corresponding key the operator has the following possibilities:

C : Continuation of measurement within measurement series of measurement mode used.
If measurements are carried out in the automatic part of this program, the previous measurement results of the present measurement series will continue to be considered in the statistical analysis. To execute additional measurements program branches to measurement menu of presently active measurement mode.

A : Continuation of measurement in automatic part of program with a new measurement series. As of now statistical analysis refers to new meas. results. Program branches to measurement menu of automatic part of program.

L : The program branches to start for reselection of the measurement parameters.

M : Program stop and return to program menu (see section 1.2).

6.7 Possibilities of Error

Before starting measurement the program checks the entered measurement parameters, such as objective magnification, measurement time and measurement distance.

If the objective chosen is not calibrated, the message below appears on the monitor:

not calibrated

If no objective magnification was assigned to the code number entered, the following is displayed on the monitor:

not used

When the combination of parameters entered is incorrect, the following comment, accompanied by a beep, is displayed on the monitor:

LINEWIDTH GREATER THAN FIELD

or

SPEED ERROR

and the program returns to start for re-input of the measurement parameters.

Another error can occur when measuring near the end of the measurement range.
If the end switch is reached during the measuring process, then the measurement will be stopped; the following message will appear on the monitor:

ENDSWITCH REACHED ?

Concurrent with this display is a beep.

Shortly after the display of this warning, the program branches to the measurement menu of the corresponding measurement mode to repeat measurement.

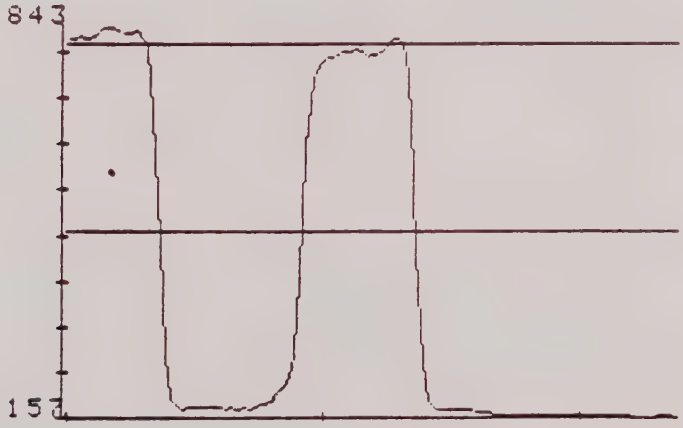
Once the measuring slit has been repositioned accordingly, the measurement can be repeated.

In the automatic part of the program it can arise that during a measurement not all of the required intersection points are found. If such is the case the measurement will be stopped, and the following message will appear on the monitor in conjunction with a beep:

Not all edges found or wrong
structure selection! ADJUST!

The intersection points are sometimes not found because, for example, the structure was incorrectly selected or the starting position of the measuring slit was bad.

In order to determine the cause of the error, it is absolutely necessary to graphically represent the measurement's intensity profile. A graph of the intensity profile is obtained by pressing GRAPH:



bad adjustment

The chosen 100% value and the threshold value are drawn in the graph.

Via the key GRAPH+COPY this graph can be printed out.

6.8 Key Functions

A clear overview of all the keys used in this program and their functions is shown below:

6.8.1 Measuring Slit Operations

HP 85 key	Function
↑	Lengthening of measuring slit
↓	Shortening of measuring slit
←	Measuring slit moves to left
INS/RPL:	Measuring slit turns counter-clockwise
-CHAR	Measuring slit turns clockwise

6.8.2 Measurement Menu

HP 85 key	Function
K1(MEAS), RUN	Start of measurement
K3(TEST), ROLL	Start of photometer check
K8(EXIT)	Program stop (see section 6.8.11)

6.8.3 Photometer Test

HP 85 key	Function
SPACE BAR	Automatic adjustment of photometer
END LINE	Stop of photometer check and return to measurement menu

6.8.4 Definition of 100% Value

HP 85 key	Function
K2(BACKGR)	Background as 100% value
K3(MAXIMUM)	Maximum as 100% value
K4(REMEAS)	Return to measurement menu with former or new measurement parameters via program stop menu (see section 6.8.11) for repeat of measurement

6.8.8 Table of Automatic Measurement Mode

HP 85 key	Function
P	Print-out of present measurement results
S	Print-out of number of measurements and statistical values, i.e. mean value and standard deviation of present measurement series
R	Repeat of existing measurement
C	Continuation of measurement within present measurement series
N	Start of a new measurement series
O	Creation of a meas. parameter set
D	Storage of measurement results
E	Program stop (see section 6.8.11)

6.8.9 Creation of Measurement Parameter Sets

HP 85 key	Function
SPACE BAR + letter (A-V)	Input of new code for meas. parameter set (A-V). Code may have 10 characters maximum.
Letter (A-V)	Storage of meas. parameter set under code letter entered
X	Stop of meas.-parameter-set formation and branching to program stop menu (see section 6.8.11)

6.8.10 Storage of Measurements Results

HP 85 key	Function
No. (1-5)	Storage of 100 meas. results maximum in DATA1-5 on system cassette

6.8.11 Program Stop

HP 85 key	Function
M	Program stop and return to program menu
C	Continuation of measurement in existing measurement mode
A	Continuation of measurement in automatic measurement mode
L	Return to program start for reselection of measurement parameters

7. Automatic Measurement on Masks and Wafers

The program "6" (OPER) was especially developed for structure width measurement in semiconductor production.

With the aid of a measurement parament set, learned in the INTAME program, the width of a chosen type of structure can be measured on as many different objects (masks or wafers) as desired. It is possible to statistically analyse the results of these measurements and to store them on the system cassette.

Since reliable and speedy work is important in production, the system was equipped with a compact keyboard with which in this program only the execution of slit operations (orientation of slit to object's structure), the checking of the photometer as well as the starting and ending of measurement is still possible.

Included in the measurement parameter set are: the chosen objective, the measurement distance, the measurement time, the expected structure width, the smoothing of the intensity profile (see previous chapter), the 100%-value definition, the threshold value and the selected measurement positions (threshold-value intersection points, minimums, maximums and mean values) of the learn measurement on a selected structure performed in the INTAME program.

7.1 Selection of the Measurement Parameter Set

When the program menu is at hand, the OPER program is called by pressing "6". After loading of the cassette the codes of the 22 possible measurement parameter sets appear on the monitor:

```
Measurement Files
A: STRUC A        B: STRUC 2
C: STRUC 3        D: STRUC 4
E: STRUC 5        F: STRUC 6
G: STRUC 7        H: STRUC 8
I: STRUC 9        J: STRUC 10
K: STRUC 11       L: STRUC 12
M: STRUC 13       N: STRUC 14
O: STRUC 15       P: STRUC 16
Q: STRUC 17       R: STRUC 18
S: STRUC 19       T: STRUC 20
U: STRUC 21       V: STRUC 22

press Code A-V
```

6.8.5 Determination of Threshold

HP 85 key	Function
K2	First threshold value
K3	Second threshold value
K4	Third threshold value

6.8.6 Selection of Measurement Positions for Structure Width Calculation

HP 85 key	Function
K1(EDGE)	Intersection point as meas. position
K2(MIN)	Minimum between two intersection pts. as measurement position
K3(MAX)	Maximum between two intersection pts. as measurement position
K4(MID)	Mean value from two intersection pts. as measurement position

6.8.7 Learn Table

HP 85 key	Function
S	Start of new measurement with former measurement parameters
N	Start of new measurement with option to change measurement parameters
G	Selection of measurement positions and structure width calculation
T	Change of three selectable threshold values and of 100% value
R	Reselection of threshold value and change of 100% value
P	Print-out of all successive intersection-point distances
D	Display of all successive intersection-point distances
L	Print-out of last meas. results
A	Branching to automatic meas. mode
O	Creation of a meas. parameter set
E	Program stop (see section 6.8.11)
GRAPH	Display of intensity profile's graph
GRAPH+COPY	Print-out of intensity profile's graph
PAPER ADVANCE	Advancement of paper

When the operator decides on one of the measurement parameter sets being offered, he must type in its corresponding code letter; the program loads this measurement parameter set into its working memory.

If it is necessary to show the individual measurement and analysis parameters of the chosen measurement parameter set, this can be affected by depression of "TEST" (orange-coloured key on HP 85).
The data of the selected measurement parameter set appear on the monitor:

```
PARAMETERS of file STRUC A
  with code A
1. Objective      :     80 x
2. Appr. CD width :  10 0 µm
3. Meas. time     :      3 sec
4. Threshold      :   50.0 %
5. Smooth-factor  :      4
6. 100%-value     :   Max
7. Meas. CD width :   10.0 µm
8. Add. corr.     :    0.0 µm
9. Mult. corr.    :    1.0 *
10.Meas. point 1  :   MID  21
11.Meas. point 2  :   MID  34

To print press COPY
```

For a print-out of this data COPY is to be pressed.

After selection of the desired measurement parameter set, the identification and code letter of the chosen measurement parameter set, in our case of the set "STRUC A", are printed out by the computer.

```
Results for file STRUC A
  with code A
```

7.2 Measurement Preparations

After selection of the measurement parameter set, the system is ready for measurement. The monitor displays the measurement menu with information about the upcoming adjustment of the measuring slit to the object's structure:

```
                    Pos.:  45.27µm
                      *
use Objective # 3    80 x


Adjust stage with cursor keys
 and labeled function keys
-----------------------------
                              EXIT
MEAS       STATIS    TEST     GRAPH
```

Adjustment of the measuring slit to the object's structure is executed using the following keys:

Compact keyboard key	HP 85 key	Function
↑	↑	Lengthening of measuring slit
↓	↓	Shortening of measuring slit
←	←	Measuring slit moves to left
→	→	Measuring slit moves to right
↖	INS/RPL	Measuring slit turns counter-clockwise
↘	-CHAR	Measuring slit turns clockwise

Furthermore the measuring slit position, in reference to an end of the travel range and to the object, is indicated in the uppermost line. In addition the relative position of the measuring slit is marked by the asterisk's position in the second line.

Before measurement can be started the photometer's signal must be checked. During a measurement this signal must remain within the range of reception, and the available intensity resolution (max. 1,024 intensity value increments) should, when possible, be fully utilized.

To check the photometer's signal the measuring slit is to be moved to the brightest spot of the structure to be investigated, and K3 (TEST) or ROLL on the HP 85 or "P" on the compact keyboard is to be pressed. The following print-out appears on the monitor:

7.3 Measurement

After the preparations have been completed, measurement can be started. By pressing either K1 (MEAS), RUN on HP 85 or "M" on the compact keyboard, the measurement is started.
It is executed according to the selected measurement parameter set.

Caution!

To avoid causing vibrations during the measurement process, do not touch the microscope. A reminder is displayed on the monitor:

```
DONT TOUCH THE MICROSCOPE
=========================
```

The end of the measurement process is indicated by a beep.

If the measurement was performed correctly, the measured and corrected structure-width value, corresponding to the selected analysis parameters (threshold value, maximum or background as 100% value, measurement-position definition), appears on the monitor:

```
Objectiv : 80 x

Dist:MID  21 to MID  34: 10.03µm
with Threshold  = 50 %
N:  2  σ: 0.02µm Mean: 10.03µm

Accept Result with  SPACE or [#]
Reject Result with K1,RUN or [M]

hold key for print

-------------------------------
                          EXIT
REJECT  STATIS            GRAPH
```

Concurrent with this display of the measurement results is a beep.
Correction of the measured value is either additive (a constant corrective amount, also named structure-width correction, is added to the measured value) or multiplicative (measured value is multiplied by a constant correction factor).
The type of correction, as also the other measurement and analysis parameters, was determined in INTAME with sample measurements.

L I G H T C O N T R O L

```
If ready press  K3, ROLL or [P]
Auto-adjust press  SPACE or [#]
 793
```

In the line above the bar (to the left) is the photometer's measured value. The length of the bar is proportional to this value.

If the measuring system is equipped with an adjustable stabilised power unit, an automatic adjustment of the illumination level is thus possible.
After pressing of the SPACE BAR on HP 85 or "#" on the compact keyboard, the level of illumination is changed until a photometer signal value of approx. 800 results. Should the illumination level exceed or fall below the aforesaid limit value, a corresponding warning is displayed on the monitor:

INCREMENT GAIN

or

DECREMENT GAIN

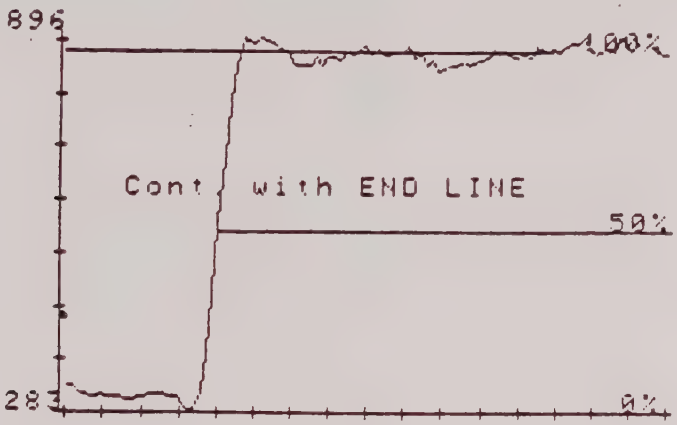
The optimal photometer signal value is also attained in this case by setting the high voltage and/or the photometer amplification.

If an automatic adjustment of the illumination level is not available, then manual adjustment of it, of the high voltage and of the photometer amplification will achieve the desired photometer signal value.

A warning signal sounds when the photometer signal exceeds a value of 1,000.

Adjustment of the photometer's signal is completed by repeatedly pressing K3 (TEST), ROLL on HP 85 or "P" on the compact keyboard.

Upon completion of the measurement, the operator can display this graph on the monitor via K4 (GRAPH):



If a print-out of this graph is desired, the COPY key must be pressed before depression of END LINE. Once END LINE has been pressed, the program returns to the menu last used (measurement or acceptance menu).

In the following example a statistical evaluation of the measured values was carried out after the 5th and 10th values in this series:

```
N:   1   Result:   9.23µm
N:   2   Result:   9.25µm
N:   3   Result:   9.27µm
N:   4   Result:   9.27µm
N:   5   Result:   9.27µm
N:   5  σ: 0.01 Mean:   9.26µm
N:   6   Result:   9.25µm
N:   7   Result:   9.25µm
N:   8   Result:   9.27µm
N:   9   Result:   9.25µm
N:  10   Result:   9.23µm
N:  10  σ: 0.01 Mean:   9.25µm
```

If a new series of measurements must be performed using the same parameters (numbering of the measurements begins with the number "1"), then "E"+"Y" on HP 85 or the compact keyboard is to be pressed in the order indicated. The program branches to its start for re-entry of the measurement parameters. The counter of the present measurements is set back, and from now on the statistical evaluation refers to the measured values of the new series.

Important!

Since a maximum of 100 readings can be stored in each of the data files DATA1-DATA5, a warning appears on the monitor as of number 100:

Buffer full! STORE with Key 'F'

The statistical evaluation of the measurement results does not have this limitation. It is concerned with the total number of measurements in the existing measurement series (more information in section 5.4 and 6.5).

5.4 Stopping the Program and Storing Data

If it is necessary to stop measurement, this is effected by pressing K8 (EXIT) on HP 85 or key "E" on the compact keyboard. The program then branches to its stopping routine, and the following display appears on the monitor:

```
Return to menu:      'M'
Continue meas.:      'N'
New meas. param.:    'Y'
Data storage:        'P'
```

The operator can now choose one of the following possibilities by pressing a corresponding key:

1. Continuation of measurement with new parameters

   After "Y" on HP 85 or on the compact keyboard has been pressed, the program returns to start to allow for redetermination of the measurement parameters (see section 5.1).

   A new series of measurements now begins, starting with the number 1. The statistical evaluation refers to the measured values of this new series.

2. Data storage

   Once "P" has been pressed (on HP 85 or the compact keyboard), the program branches to its storing routine for measurement data.
   The following print-out is displayed on the monitor:

```
STORE DATA 1-100 TO FILE #?
  1..5
```

   By typing in the corresponding number, the operator has the possibility of storing the first 100 corrected measurement results in one of the data files DATA1-DATA5.

   Once the system has stored this data, it indicates the following on the monitor:

Stored to file DATA1

This tells the operator in which memory location the measurement results were stored.

After this display the system branches to the measurement menu (see section 5.2) to enable the operator to perform further measurements.

The measurement counter is set back, and from now on the statistical evaluation refers just to the measured values of the new measurement series.

From the existing series of measurements all the measurement results, together with their statistical analysis and the structure-width correction used are stored (for details see section 6.5).

3. Continuation of measurement with same measurement parameters

   Should the operator decide upon continuation of measurements within the measurement series at hand, then he must press "N" on HP 85 or on the compact keyboard. The program will return to the measurement menu.

4. Return to program menu

   If the operator decides to stop measurement within this program, he must press key "M" on HP 85 or on the compact keyboard. Execution of the program is thereby stopped, and the program branches to the program menu to allow for selection of a new program (see section 1.2).

5.5 Possibilities of Error

Before starting the measurement process, the program checks the entered measurement parameters in reference to their conformity to the measuring system. When these parameters have been incorrectly entered, the following explanation appears on the monitor, concurrent with a beep:

not calibrated

when the objective is not calibrated,

not used

when an objective was not assigned to the chosen code number,

LINEWIDTH GREATER THAN FIELD

when the combination of objective and measurement distance was incorrectly selected or

SPEED ERROR

when a measurement distance which is too long was selected. Since the measurement time is fixed, the speed resulting from too long of a measurement distance cannot be accepted by the measuring system.

After displaying one of these error messages, the program returns to start for re-input of the measurement parameters.

Another error can occur when measuring near the end of the measurement range.
If the end switch is reached during the measurement process, then the question below appears, in connection with a beep, on the monitor:

ENDSWITCH REACHED ?

After repositioning the measuring slit correspondingly, the measurement can be repeated.

Another error can occur, if the structure to be measured is not entirely within the measurement distance. In such a case the system displays the following explanation on the monitor:

```
Not all edges found or wrong
structure selection
```

This error can be corrected by repositioning of the measuring slit.

If the measured structure width is much greater or smaller than that entered, the system displays the indication shown below on the monitor:

```
Measurement more than 150%
or less than 50% of
estimated length! ADJUST!
```

This measurement error can be caused by vibrations or electrical disturbances. These distort the intensity profile from which the structure width is determined, thus yielding an incorrect value.

Trouble shooting!

Display the intensity profile in graph form on the monitor with the entered threshold value and measurement positions (see section 5.3). With the intensity profile in view, the cause of error can be readily determined.

5.6 Key Functions

A clear overview of all the keys used in this program and their functions is shown below:

Pos.	Compact keyboard	HP 85 key	Function
1	↑	↑	Lengthening of measuring slit
2	↓	↓	Shortening of measuring slit
3	←	←	Measuring slit moves to left
4	→	→	Measuring slit moves to right
5	↖	INS/RPL	Measuring slit turns counter-clockwise
6	↗	-CHAR	Measuring slit turns clockwise
7		K1(MEAS)	Start measurement
8	M	RUN	Start measurement
9		K1(MEAS)+ K1(REJECT)	Non-acceptance of measurement results
10	M+M	RUN+RUN	Non-acceptance of measurement results
11		SPACE BAR	Short depression:acceptance of meas.results w/o print-out Long depression:acceptance of meas. results with print-out
12		K3(TEST)	Start photometer check
13	P	ROLL	Start/stop photometer check
14	E+Y	K8(EXIT)	Enter new measurement parameters
15	E+P	K8(EXIT)	Store meas. results in DATA1-DATA5
16	E+N	K8(EXIT)	Continue measurements within present series
17	E+M	K8(EXIT)	Stop program, return to program menu
18		K2(STATIS)	Print statistical values of present measurement series
19		K4(GRAPH)	Display intensity profile as graph on monitor
20	E	K8(EXIT)	Program branches to stopping routine (see position 14-17)

6. Interactive Measurement on Masks and Wafers

Program "5" (INTAME) interactively measures structure widths on masks and wafers, is organized as a learning program in preparation for program "6" (OPER) and allows for individual adaptation to complex problem-solving in structure width measurement.

By typing in number "5" the INTAME program is loaded. Loading and transmitting takes approximately 1-2 minutes in the computer.

6.1 General Information about the System

When the program has been transmitted, the following text appears for approximately 3 seconds on the monitor:

```
Leitz CD MEASURING Program
        INTAME

for interactive and automatic
measurements on masks and wafer
```

Thereafter code data about the objectives appears on the monitor:

```
THE FOLLOWING OPTICS ARE
CALIBRATED:

# 1 :  16x     16.17
# 2 :  32x     32.16
# 3 :  80x     81.14
# 4 uncalibrated or unused
# 5 : 160x    158.00

To continue press END LINE
```

The operator is informed which objectives can be used, their actual magnifications after calibration and under which number the individual objectives are to be called.

Before input of the measurement parameters is begun, information concerning the calibration standard and the grating constant last used in program CALGRT will appear on the monitor after END LINE has been pressed.

Calibrated with
LEITZ
Calibration width: 10 µm

In addition the threshold value, last determined in program CALSTR during calibration with a reference structure, will be indicated:

Threshold of Program 3 was
29.4 %

In the following threshold determination, the operator can decide to continue using this threshold value and, if necessary, store it in a set of measurement parameters.

6.2 Selection of the Measurement Parameters

Once END LINE has been pressed, the input procedures begin in the form of a dialogue.

The operator must determine the following measurement parameters:

1. Three threshold values, from which the operator choses one suitable for the measurement
2. Objective magnification
3. Approximate structure width
4. Additive and/or multiplicative structure-width correction
5. Smoothing of the intensity profile (smoothing factor)
6. Measurement time

In this dialogue each individual entry of a measurement parameter is to be completed with END LINE.

After this program has been called, the operator will be offered preset values for each measurement parameter or the measurement parameter values last used.

First of all three threshold values are to be defined, from which the operator can select a suitable one according to the measured intensity profile. The input is in percent.

During input it is to be noted that 0% corresponds to the minimum and 100% to a definite value (maximum or background; see section 6.4.2) of the intensity profile.

The operator is offered preset threshold values of 20%, 40% and 60%. These can be accepted or modified by entering corresponding values.

In the following example the threshold values of 33%, 50% and 75% were chosen:

```
Enter threshold values

T 1   = 20 %?
33
T 2   = 40 %?
50
T 3   = 60 %?
75
```

With the next input the objective magnification is determined. Once the objective has been selected, the system checks if the number entered was assigned an objective and, if yes, if this objective is calibrated. Should no serviceable objective be found under the number, then the following comment appears on the monitor:

not calibrated

or

not used

In our example the objective 80X has been chosen:

```
Please enter objective # 1  16 X
 80 x
```

The next value to be determined is the approximate width of the structure to be measured. The operator is offered a preset structure-width value of 5 µm.
In our example we chose the approximate structure-width value of 15 µm:

```
Enter approx. structure
width (µm) 5
?
15
```

Important!

Approximate structure width can also be determined in the following manner:

1. Input of desired objective's code number.
2. Take-over of values offered by system for other measurement parameters.
3. Moving of measuring slit to edges of structure to be measured and holding of the corresponding position values (top line of measurement menu on monitor display).
4. Determination of the approximate structure width by calculating the difference of these two position values.
5. Return from measurement menu via EXIT to program start to enter remaining measurement parameters.
6. Input of determined approximate structure width.

With the next input the structure-width correction is defined. In this program it can be additive as well as multiplicative.

The corrected measured value results from the correction factors and the measured value:

corrected measured value = (measured value) X (multiplicative factor) + (additive constant)

The possibility of correcting the measured value is especially important for light-optical structure width measurements (in our case with MPV-CD), since a precise absolute measurement is not possible in the micron range.

In practice the width of the structure to be measured is determined, for example, by electron optics and used as nominal width by this measuring system.

The operator is offered the additive and multiplicative structure-width corrections (constant and factor) last used during the present objective magnification:

```
Additive correction: - 25 µm
Multipl. correction: 1 x

Change: 'Y'/'N'      (Yes/No)
```

To accept these values the operator must press key "N" (No), otherwise "Y" (Yes) is to be pressed. In the latter case the program branches for reselection of the desired structure-width corrections:

```
Enter offset?
0
Enter factor?
1
```

In our example we have decided upon an additive structure-width correction of 0 µm and a factor of 1.

With the next input the smoothing factor is established. This parameter determines smoothing of the intensity profile through the software. The greater the smoothing factor, the more smoothing of the intensity profile will be performed.

With intensity profiles of contrast-poor and reflectively-weak specimens, it is necessary to suppress noise for the determination of structure widths.
One obtains satisfactory results with these specimens by using a smoothing factor of "7". With other objects it is sufficient to use "3" as the smoothing factor.

In our example we choose "4" as the smooth number:

```
Smooth (0= no smoothing
        1-9  =smooth number) 0
 4
```

The last measurement parameter to be chosen is the measurement time. It can be from 1 to 9 seconds, its duration depending on the type of problem. In most cases 3 seconds scan time is sufficient for carrying out the measurement.
The operator is offered a preset value of 5 seconds.

In our example we have decided upon a measurement time of 3 seconds:

```
Enter scan time          5
(1...9 sec per structure)
 3
```

6.3 Measurement Preparations

After input of the measurement parameters has been completed, the system is ready for measurement. The monitor displays the measurement menu with information about the required adjustment of the measuring slit to the object's structure:

```
                    Pos.:   51.18µm
                            *

Adjust stage with cursor keys
 and labeled function keys
-----------------------------
                              EXIT
MEAS                  TEST
```

Adjustment of the measuring slit to the object's structure is executed using the following keys:

HP85 key	Function
↑	Lengthening of measuring slit
↓	Shortening of measuring slit
←	Measuring slit moves to the left
→	Measuring slit moves to the right
INS/RPL	Measuring slit turns counter-clockwise
-CHAR	Measuring slit turns clockwise

Furthermore the measuring slit's position, in reference to an end of the travel range and to the object, is indicated in the uppermost line. In addition the measuring slit's relative position is marked by the position of an asterisk * in the second line.

Before measurement can be started the photometer's signal must be checked. During a measurement this signal must remain within the range of reception, and the available intensity resolution (max. 1,024 intensity value increments) should, when possible, be fully utilized.

To check the photometer's signal, move the measuring slit to the brightest spot of the structure to be investigated. Press K3 (TEST) or ROLL. The following print-out appears on the monitor:

7.4 Stopping the Program and Storing Data

If it is necessary to stop measurement, this is effected by pressing K8 (EXIT) on HP 85 or key "E" on the compact keyboard. The program then brances to its stopping routine, and the following display appears on the monitor:

```
Return to menu:      'M'
Continue meas.:      'N'
New param. set:      'Y'
Data storage:        'P'
```

The operator can now choose one of the following possibilities by pressing a corresponding key:

1. Reselection of a measurement parameter set

   After "Y" on HP 85 or the compact keyboard has been pressed, the program returns to start for redetermination of the measurement parameter set (see section 7.1).

2. Measurement data storage

   Once "P" has been pressed on HP 85 or the compact keyboard, the program branches to its storing routine for measurement data.
   The following print-out is displayed on the monitor:

```
STORE DATA 1-100 TO FILE #?
  1..5
```

   By pressing one of the keys 1-5, the operator has the possibility of storing the first 100 corrected measurement results in one of the data files DATA1-DATA5.
   Once storage of the measurement results in the selected file on the system cassette is completed, the system displays the following message on the monitor:

```
Stored to file DATA1
```

Afterwards the program returns to start for redetermination of the measurement parameter set (see section 7.1).

The measurement counter is set back, and from now on the statistical analysis refers just to the measured values of the new measurement series.

Together with the measurement results the statistical analysis of this data and the structure-width correction used are stored (for details see section 6.5).

3. Continuation of measurement with same measurement parameters

   Should the operator decide upon continuation of measurement within the present measurement series, then he must press "N" on HP 85 or the compact keyboard. The program returns to the measurement menu.

4. Return to program menu

   If the operator decides to stop measurement within this program, he must press key "M" on HP 85 or the compact keyboard. Execution of the program is thereby stopped, and the program branches to the program menu (see section 1.2) to allow for selection of a new program.

7.5 Possibilities of Error

Since the entered measurement parameters were already checked for suitability with the system during "learning" in the INTAME program, a check will not be performed in this program.

The checks in this program are limited solely to checking the measuring-slit position during measurement procedures (measurement-distance limitation: travel to the end stops), checking the measured width and the type of structure.

If the end switch is reached during the measuring process, then the following question appears on the monitor in connection with a beep:

```
ENDSWITCH REACHED ?
```

After repositioning the measuring slit correspondingly, the calibration measurement can be repeated.

If the measurement process was successful, the structure width is defined with the measured intensity profile and the previously given analysis parameters.

If this defined structure width is 50% greater or less than the "learned" structure width, the monitor displays the following comment:

```
Measurement more than 150%
or less than 50% of
estimated length! ADJUST!
```

and the program branches to the measurement menu.

An additional error can arise when the required measurement positions (minimum, maximum, etc.) are not found on the intensity profile. In such a case the system displays the following message on the monitor:

Not all edges found or wrong structure selection! ADJUST!

Course of Action :

Graphic representation of intensity profile with entered analysis parameters (threshold value, 100% value, measurement positions) on monitor (see section 7.3). With the intensity profile in view the cause of error can be readily determined.

7.6 Key Functions

A clear overview of all the keys used in this program and their functions is shown below:

Pos.	Compact keyboard	HP 85 key	Function
1	↑	↑	Lengthening of measuring slit
2	↓	↓	Shortening of measuring slit
3	←	←	Measuring slit moves to left
4	→	→	Measuring slit moves to right
5		INS/RPL	Measuring slit turns counter-clockwise
6		-CHAR	Measuring slit turns clock-wise
7		K1(MEAS)	Start measurement
8	M	RUN	Start measurement
9		K1(MEAS)+ K1(REJECT)	Non-acceptance of measurement results
10	M+M	RUN+RUN	Non-acceptance of measurement results
11		SPACE BAR	Short depression:acceptance of measurement results Long depression:acceptance + print-out of meas. results
12		K3(TEST)	Start/stop photometer check
13	P	ROLL	Start/stop photometer check
14	E+Y	K8(EXIT)	Load a new measurement para-meter set
15	E+P	K8(EXIT)	Store measurement results in DATA1-DATA5
16	E+N	K8(EXIT)	Continue measurement within present measurement series
17	E+M	K8(EXIT)	Stop program, return to pro-gram menu
18		K2(STATIS)	Print statistical values of present measurement series
19		K4(GRAPH)	Display intensity profile as graph on monitor
20	E	K8(EXIT)	Program branches to stopping routine (see position 14-17)

We reserve the right to modify the software.

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